AMERICAN TRANSMISSION COMPANY
THE ENERGY ACCESS COMPANY

# Weston 4 Generator
# Interim System Stability Report

Covering the Generator Test and
Post Arrowhead-Stone Lake Periods

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# Summary

Weston 4, a 550 MW (net) generator located near Wausau, Wisconsin, is scheduled to begin testing in December 2007 and go commercial in June 2008. ATC is implementing two Special Protection Systems (SPSs) to maximize Weston generation before the Arrowhead-Stone Lake (May 2008) and Gardner Park-Highway 22 (December 2009) 345 kV lines are completed. These SPSs require tripping Weston 4, reducing Weston 4 generation and/or shutting off Weston generators 3 or 31, under specific conditions to prevent multiple units from tripping.

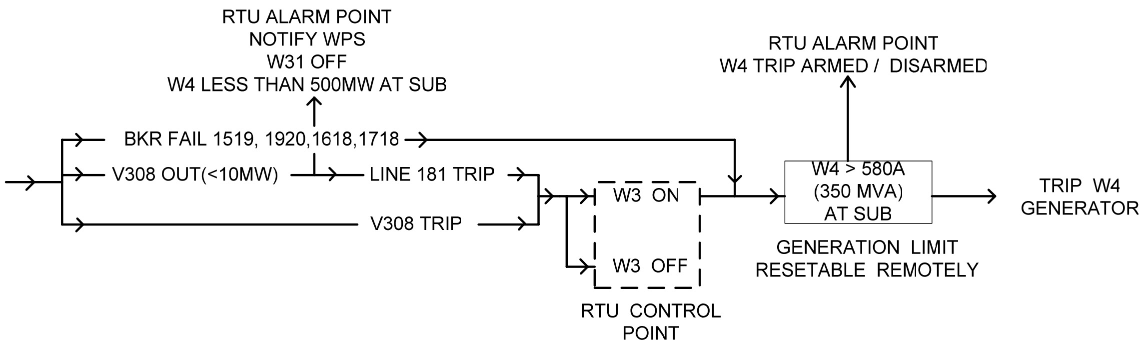


**Figure A: SPS Prior to Arrowhead-Stone Lake 345 kV Line in Service.**

The Weston 4 SPS required prior to Arrowhead-Stone Lake going into service is shown in Figure A. Weston 4 tripping is armed only if unit net output is greater than 580A (350 MW). Under intact system conditions failure of Gardner Park 345 kV breaker 1519, 1920, 1618 or 1718 will trip Weston 4 (if Weston 4 > 350 MW). When the Gardner Park-Rocky Run 345 kV line (V-308) is out of service a fault on the 115 kV Weston-Rocky Run (T-20) or 345 kV Stone Lake-Gardner Park (GDP181) line could result in generator instability. Because the protection scheme only monitors 345 kV faults on elements connected to Gardner Park, a remote terminal unit (RTU) alarm point notifies Wisconsin Public Service (WPS) when V-308 is out so they can take Weston 31 off line and reduce Weston 4 net generation to less than 500 MW to prevent generator instability. With V-308 out a GDP181 fault will trip Weston 4 unless Weston 3 is off, as determined by an operator controlled RTU point, or Weston 4 output is less than 350 MW. A V-308 fault will lead to generator instability if T-20 or GDP181 is out of service. Because the protection scheme does not monitor 115 kV line outages, Weston 4 will be tripped for all V-308 faults, if Weston 3 is in service and Weston 4 generation is > 350 MW.

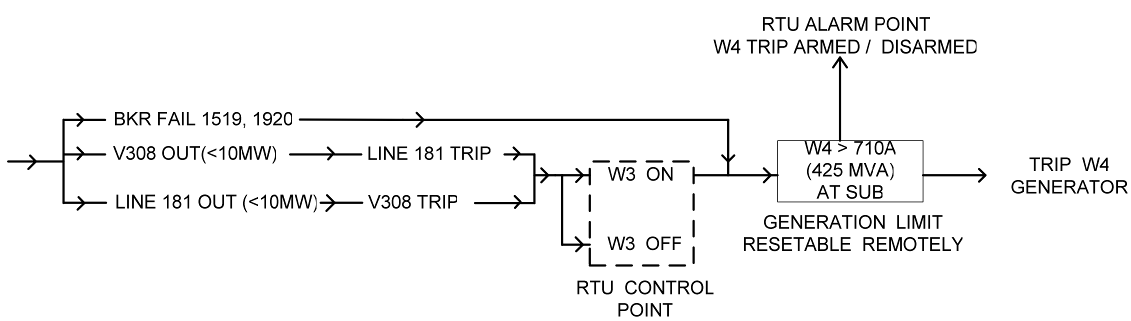


**Figure B: Weston 4 Tripping Scheme Prior to Highway 22 345 kV Lines in Service.**

The SPS used after the Arrowhead line is in service, but before the Highway 22 line is in service (Figure B), arms Weston 4 tripping if Weston 4 net generation is above 710 A (425 MW). Under intact system conditions failure of Gardner Park 345 kV breaker 1519 or 1920 will trip Weston 4 if Weston 4 generation is > 425 MW. A fault on either V-308 or GDP181 with the other out of service will trip Weston 4 to prevent multiple unit trips, unless Weston 3 is off or Weston 4 generation is < 425 MW. No SPS is necessary once both the Arrowhead and Highway 22 lines are in service.

# I. Introduction

The Weston substation is located just south of Wausau, Wisconsin. In September 2002, when Wisconsin Public Service (WPS) publicly announced its intention to construct the 550 MW (net) Weston Unit 4 generator (Weston 4) with a proposed in service date of June 2008, the substation included five generating units, five 115 kV transmission lines and one 115/345 kV transformer connecting a single 345 kV line to the substation (Figure 1). The generating units include 3 coal fired base units and 2 gas fired peaking units. The base units are Unit 1, 60 MW built in 1954, Unit 2, 76 MW built in 1960, and Unit 3, 300 MW built in 1981. The peaking units are Unit 31, 22 MW built in 1969, and Unit 32, 50 MW built in 1973. Although the existing substation satisfies all reliability criteria for the existing generation, the addition of 550 MW of generation was determined to require substantial system upgrades.

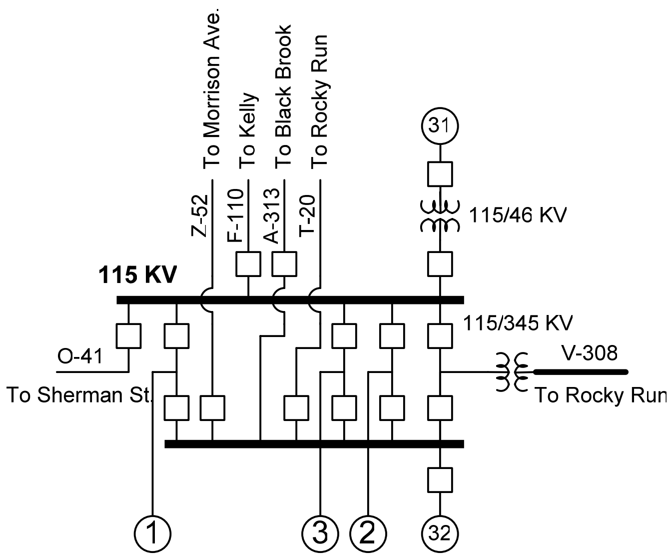


**Figure 1: Weston Substation before Weston 4 Announced.**

At the time of WPS's announcement of their intention to build Weston 4, the American Transmission Company (ATC) already had plans to upgrade the system near Weston. The planned upgrades included (1) a 50 mile 345 kV line from the Morgan substation located near Oconto Falls, Wisconsin, to a new substation named Werner West located near New London, Wisconsin, (2) a 220 mile long 345 kV line from the Arrowhead substation, located near Duluth, Minnesota, to the existing Stone Lake substation, near Stone Lake, Wisconsin, to a new substation near Weston named Gardner Park, (3) new 345 kV substations at Gardner Park and Werner West, (4) replacing the single 230 MVA 345/115 kV transformer at Weston with two 500 MVA transformers at Gardner Park, (5) installing a single 500 MVA 345/138 kV transformer at Werner West, and (6) upgrading the Weston 115 kV bus, other lower voltage transformers and lines near Weston.

The ATC planned upgrades in the Wausau area were initially expected to be in service prior to Weston 4. By September 2003, a year after WPS announced Weston 4, the Arrowhead line completion date was pushed back to June 2008, six months after Weston 4 will begin testing, and the Morgan-Werner West line was pushed back to December 2009, 2 years after testing will begin. An additional transmission upgrade required for the interconnection of Weston 4 was a new 50 mile 345 kV line from Gardner Park to Highway 22, which will be a new switching station connected to the Morgan-Werner West line south of Belle Plaine, Wisconsin. This new line from Gardner Park to Highway 22 was scheduled to be in service at the same time as Morgan-Werner West. These three lines are stability related required upgrades that need to be service for Weston 4 to generate its full output.

Initial stability simulations showed that to maintain generator stability Weston 4 generation would have to be limited to 250 MW before the Arrowhead to Gardner Park line goes into service and 400 MW before the Gardner Park to Highway 22 line is completed. For economic, reliability and system security reasons, it was determined that an operating guide and/or SPS that would allow full Weston 4 generation under as many system conditions as practical would be pursued. A key component of this scheme is an SPS that would trip Weston 4 for specific faults to prevent multiple Weston generators from tripping.

## II. Generator Interconnection Facilities Studies

The Weston 4 Facilities Study Report, including four addendums, was prepared by ATC and posted by MISO between September 2003 and June 2005. While these reports were being prepared changes were made to the competing generator requests, system and substation configurations and interim system protection philosophies. This analysis determined that full output of Weston 4 could be achieved only after the planned Arrowhead-Stone Lake-Gardner Park, Morgan-Highway 22-Werner West and Gardner Park-Highway 22 345 kV lines were in service (Figure 2). Additional system upgrades required for Weston 4 included thermal upgrades to existing system equipment and short circuit related breaker replacements.

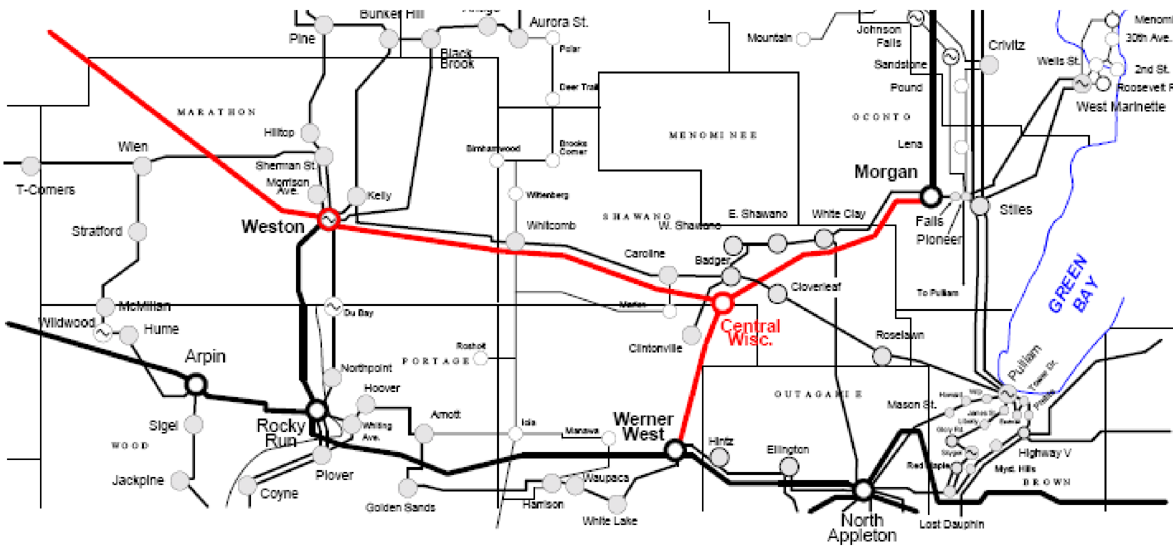


**Figure 2: Area near Weston with 345 kV Lines Required for Full Weston 4 Output.**

The Facilities Studies performed for Weston 4 included thermal, short circuit and stability analysis. The thermal analysis found several system upgrades required to allow full Weston 4 output, particularly before the required stability upgrades are in service. Short circuit analysis found several required breaker replacements. All required thermal and short circuit upgrades will be in service before Weston 4 testing begins. However, the required stability related system upgrades (i.e. the 345 kV lines) would not be in service prior to unit testing and/or commercial operation.

Several potential 345 kV lines, in addition to the already planned Arrowhead-Stone Lake-Gardner Park line, were considered as stability fixes for Weston 4. The line determined to be the best fix for multiple reasons was a line from Gardner Park to Highway 22, a point along the planned 345 kV line from Morgan to Werner West. The final Gardner Park/Weston substation (Figure 3) included terminals for Weston 4, the new 345 kV lines, two 345/115 kV transformers as well as 115 kV bus modifications to the aging Weston 115 kV bus to upgrade the substation to today's standards. Given the limited space at the Weston substation, the Gardner Park substation includes a 115 kV bus approximately one mile from the existing Weston 115 kV bus.

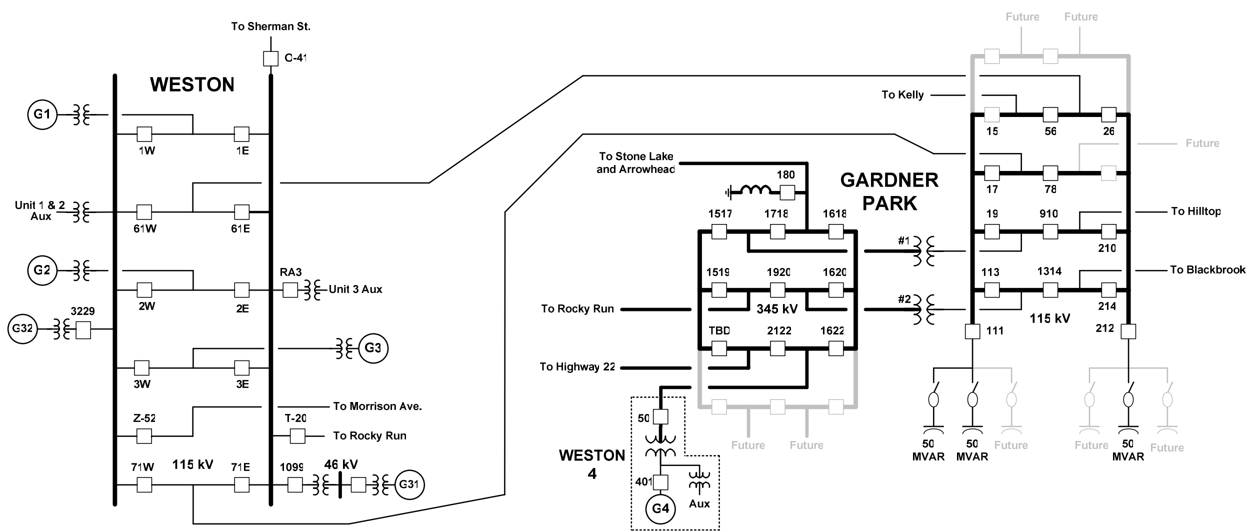


**Figure 3: New Weston and Gardner Park Substations.**

The Gardner Park-Highway 22 line is scheduled to be put into service at the same time as the Morgan-Highway 22-Werner West line, but this will not be until December 2009, approximately 18 months after Weston 4's scheduled commercial in service date, June 2008, and approximately two years after Weston 4 will begin testing. Although the Stone Lake-Gardner Park portion of the Arrowhead-Stone Lake-Gardner Park line is already in service, the Arrowhead-Stone Lake portion of the line will not be in service until after Weston 4 unit testing has begin. Because these lines are stability fixes, they have to be in service when the unit is being tested at full power or else an operating guide, special protection system (SPS) or remedial action scheme will have to be in place.

The economic, reliability and system security benefits of having Weston 4 available as soon as possible, made designing a way to maximize Weston 4 output a primary focus of the Facilities Study Addendums. Initially, there were the two competing generator requests and multiple Gardner Park/Weston bus designs to consider. Looking at multiple system configurations and faults on essentially every Weston and Gardner Park line and transformer under intact system conditions and several faults under multiple outage conditions made running hundreds of stability simulations necessary. Even after competing generators dropped out and the bus configuration was finalized, there were still three system configurations to consider (1) before Arrowhead-Stone Lake and Gardner Park-Highway 22 in service, (2) before Gardner Park-Highway 22 in Service, and (3) both Arrowhead-Stone Lake and Gardner Park-Highway 22 in service. Under condition (3) all required fixes would be in place and no SPS, Operation Guide, or remedial action would be necessary.

Several schemes for maximizing Weston 4 output were considered. These included adding fast valving controls, reducing Weston 4 output, reducing other Weston generator output, tripping Weston 4 for certain faults and tripping Weston 3 for certain faults. Initial simulations showed that to keep all Weston generators stable under intact system conditions, Weston 31 (22 MW) and 32 (50 MW) would have to be out of service and Weston 4 generation would have to be reduced to 250 MW before Arrowhead-Weston was in service and 400 MW before Gardner Park-Highway 22 was in service. The allowable Weston 4 generation could be increased to its maximum capability if Weston 3 or Weston 4 generation were tripped for certain faults under most bus configurations.

During this analysis it soon became apparent that the benefits of a complex SPS that tripped various generators for various faults under various system conditions could be outweighed by the complexities of implementing and maintaining such an SPS, even if the SPS were only temporary. Based on simulation results and the desire for SPS simplicity, it was decided that a satisfactory protection scheme that only trips the Weston 4 generator (20 kV) breaker only for certain faults on 345 kV elements connected to

Gardner Park could be designed. This would eliminate the need for communications between substations and would not require any reduction in Weston 4 generation under intact system conditions.

## III. Final Dynamic Stability Simulations and Results

A final set of simulations were performed prior to the SPS design so that the most current generator and system data could be used. All simulations were performed, as was done previously, with 50% load levels modeled in ATC areas along with Weston 4 operation near unity power factor to simulate worst case stability conditions. The idea of only tripping Weston 4 for 345 kV faults on lines connected to Gardner Park was also maintained, but there were some changes in these final simulations. A 115 kV line, J-36 from Kelly to Whitcomb, that will have to be taken out of service for the construction of the Gardner Park-Highway 22 line was taken out of service in the model and Weston 4's auxiliary load was modeled explicitly, rather than netted with unit generation.

Another change that was made for the final analysis was the addition of a Weston 4 trip for a breaker failure event. The breaker failure events were simulated by putting a 3-phase fault on a 345 kV line for 4.5 cycles (primary clearing time plus a margin). The fault was then changed to a single line-to-ground fault and applied for 5 more cycles to simulate the failure of one phase of the breaker (all 345 kV breakers at Gardner Park are independent pole operation (IPO) implementation) and then the fault was cleared. Weston 4 was tripped one cycle after the fault was cleared because the 20 kV breaker that will trip Weston 4 is a 3 cycle breaker while all 345 kV breakers at Gardner Park are 2 cycle breakers. Previous simulations tripped the unit at 4.5 cycles in anticipation of a breaker failure event when a fault occurred on a line where breaker failure would be a problem. Later simulations showed that waiting until breaker failure had occurred to trip Weston 4 was actually better for the stability of the remaining Weston units than tripping Weston 4 in anticipation of breaker failure. This was determined to be because keeping Weston 4 in service during the single line-to-ground portion of a breaker failure event helped support Gardner Park and Weston voltages, reducing the impact of the fault on the remaining Weston units.

ATC stability criteria requires simulating several different types of faults including intact system close-in and remote 3-phase line or transformer faults with breaker failure, intact system single line-to-ground bus faults with breaker failure and 3-phase faults cleared in primary time with a prior outage of a transmission element. Three-phase faults cleared in primary time with an otherwise intact system are usually not run because they are less severe than intact system breaker failure and prior outage primary clearing time faults. Remote 3-phase faults with breaker failure are usually less severe than close-in three phase faults with breaker failure, but they were run for events that were problems for close-in faults because the longer clearing times of remote faults can make them a problem.

Three-phase fault breaker failure simulations were run for every Gardner Park and Weston line and transformer. If multiple breaker failure scenarios were possible for a system element, the worst case scenario was run first. If it was found to be a problem, the other breaker failure scenarios were run. For example a fault on the Stone Lake-Gardner Park 345 kV line can have either breaker 1718 fail and trip Garner Park Transformer #1 or breaker 1618 fail and have no additional system equipment, other than a bus segment, trip. If a breaker 1718 failure caused a problem, the 1618 failure would be simulated; if it did not, 1618 failure was assumed to not cause any problems and was not simulated. Breaker failure events that resulted in generator instability are listed in Table 1.

**Table 1: Breaker Failure Events Resulting in Generator Instability. Kelly-Whitcomb and Highway 22 Lines out of Service in All Cases. .**

| Faulted Element | Fault Location(s) | Failed Breaker | Additional Element Tripped | Problem in 2007* | Problem in 2008* |
|---|---|---|---|---|---|
| Gardner Park-Rocky Run 345 kV | Close-In & Remote | 1920 | Gardner Park 345/115 kV #2 | Yes | Yes |
| Gardner Park-Rocky Run 345 kV | Close-In & Remote | 1519 | None | Yes | Yes |
| Gardner Park 345/115 kV #2 | Close-In Only | 1920 | Gardner Park-Rocky Run 345 kV | Yes | Yes |
| Gardner Park-Stone Lake 345 kV | Close-In Only | 1618 | Gardner Park 345/115 kV #1 | Yes | No |
| Gardner Park-Stone Lake 345 kV | Close-In Only | 1718 | None | Yes | No |

*2007 – Before Arrowhead-Stone Lake 345 kV line is in Service, 2008 – Before Highway 22 lines in Service.

Prior outage simulations included outages of critical lines into Gardner Park and Weston followed by the most severe system faults. System elements outaged included all three 345 kV lines into Gardner Park (Rocky Run, Arrowhead/Stone Lake, and Highway 22) as well as a Gardner Park 345/115 kV transformer, a Gardner Park-Weston 115 kV line and the 115 kV line from Weston to Rocky Run. Prior outage events that resulted in generator instability are listed in Table 2.

**Table 2: Prior Outage Events Resulting in Generator Instability. Kelly-Whitcomb and Highway 22 Lines out of Service in All Cases. .**

| Faulted Element | Prior outage | Fault Location | Problem in 2007* | Problem in 2008* |
|---|---|---|---|---|
| Gardner Park-Rocky Run 345 kV | Gardner Park-Stone Lake 345 kV | Gardner Park 345 kV | Yes | Yes |
| Gardner Park-Stone Lake 345 kV | Gardner Park-Rocky Run 345 kV | Gardner Park 345 kV | Yes | Yes |
| Gardner Park-Rocky Run 345 kV | Weston-Rocky Run 115 kV | Gardner Park 345 kV | Yes | No |
| Weston-Rocky Run 115 kV | Gardner Park-Rocky Run 345 kV | Weston 115 kV | Yes | No |

*2007 – Before Arrowhead-Stone Lake 345 kV line is in Service, 2008 – Before Highway 22 lines in Service.

All of the events that cause generator instability can be avoided by tripping Weston 4 generation. Only one event that causes generator instability does not involve a Gardner Park 345 kV fault and will require a solution other than tripping Weston 4. This is a fault on the Weston-Rocky Run 115 kV line when the Gardner Park-Rocky Run 345 kV line is out of service before the Arrowhead-Stone Lake line is in service. The solution for this fault under prior outage conditions is to take Weston Generator 31 out of service and reduce Weston 4 generation to less than 500 MW when the Gardner Park-Rocky Run 345 kV line is out of service before the Arrowhead-Stone Lake 345 kV line is in service.

Several different fixes and system conditions were investigated to determine the optimum solutions for the simulated generator stability problems. These included (1) tripping Weston 4, (2) taking other Weston generators out of service, (3) reducing Weston 4 generation, and (4) looking at the necessity of a fix under increased ATC load conditions. In addition, the studied fault type was varied to determine if the scheme should only operate for three or multi-phase faults.

The tripping of Weston 4 has been discussed above. Other possible mitigating measures included placing operating restrictions on other units at the Weston power plant. Because the small (20 MW) Weston 31 generator was the first to go unstable in some cases, the effect of having Weston 31 out of service was examined. Removal of Weston 31 from service did result in fewer Weston 4 generation restrictions. Finally, system load levels were varied but most scenarios did not identify improvement even under summer peak load conditions. However, a combination of other Weston unit operating restrictions and system load level was effective for a limited set of conditions.

The response of the system to single line-to-ground rather than three-phase faults was simulated to determine if the proposed protection scheme could be bypassed for the more common single line-to-ground faults. There was not a significant reduction in the number of events resulting in generator instability with single line-to-ground rather than 3-phase faults modeled, so designing different protection schemes for single and three phase faults was not pursued.

Table 3 lists the required actions or system conditions necessary to prevent generator instability under intact and prior outage conditions. The Appendix to this report summarizes stability simulation results of interest and includes an expanded version of Table 3, with additional presently unanticipated system conditions included. In all cases tripping Weston 4 prevented other generators from going unstable, which is the basis for the planned SPS. Alternatively, the following were possible solutions if the SPS was not pursued:

- Taking Weston 4 out of service or reducing its generation to 350 MW or less (before Arrowhead-Stone Lake is in service) or 425 MW (before the Highway 22 lines are in service) also prevented any other generators from going unstable.
- Higher levels of Weston 4 generation were acceptable for some prior outage conditions, such as up to 425 MW (before Arrowhead-Stone Lake is in service) or 475 MW (before the Highway 22 lines are in service) during a Gardner Park-Stone Lake line outage.
- Increases in allowable Weston 4 generation were also seen when the 20 MW Weston 31 generator was out of service.
- Taking Weston 3 generation out of service, rather than Weston 4, prevented generator instability for the prior outage cases of concern.
- When the Gardner Park-Rocky Run 345 kV line is out of service, outage of both the Weston 2 and 31 generators prevented generator instability.
- Although ATC loading had to be 100% or greater to prevent generator instability with all Weston generators in service, if Weston 31 generation was taken out of service ATC load as low as 60% could prevent generator instability in some prior outage cases.

**Table 3: Actions or Conditions Necessary to Prevent Generator Instability.**
**Kelly-Whitcomb and Highway 22 Lines out of Service in All Cases. .**

| Outage | Fixes | Before Arrowhead-Stone Lake | Before Highway 22 Lines |
|---|---|---|---|
| None | Breakers Failures that Trip Weston 4 | 1519*, 1920**, 1718***, 1618*** | 1519*, 1920** |
| | Unit Outage(s) | Weston 4 | Weston 4 |
| | Reduce Weston 4 Generation to: | ≤ 350 MW | ≤ 425 MW |
| | ATC Load Must Be ≥ | >100% (i.e. not a fix) | 100% |
| GPK-SLK 345 (GDP181) | Trip Weston 4 for faults on | V-308 | V-308 |
| | Unit Outage(s) | Weston 3 or 4 | Weston 3 or 4 |
| | Reduce Weston 4 Generation to: | ≤ 425 MW[2] | ≤ 475 MW |
| | ATC Load Must Be ≥ | >100% (i.e. not a fix)^^ | >100% (i.e. not a fix)^ |
| GPK-RRN 345 (V-308) | Trip Weston 4 for faults on | GDP181 or T-20 | GDP181 |
| | Unit Outage(s) | Weston 3 or 4 or 2 & 31 | Weston 3 or 4 or 2 & 31 |
| | Reduce Weston 4 Generation to: | ≤ 350 MW[1] | ≤ 450 MW[1] |
| | ATC Load Must Be ≥ | >100% (i.e. not a fix)^ | 100%^ |
| WES-RRN 115 (T-20) | Trip Weston 4 for faults on | V-308 | No Generator Instability |
| | Unit Outage(s) | Weston 3 or 4 | No Generator Instability |
| | Reduce Weston 4 Generation to: | ≤ 425 MW[2] | No Generator Instability |
| | ATC Load Must Be ≥ | >100% (i.e. not a fix)^^ | No Generator Instability |

*Gardner Park-Rocky Run 345 kV Line Fault
**Gardner Park-Rocky Run 345 kV Line or Gardner Park 345/115 kV Transformer #2 Fault
***Gardner Park-Stone Lake 345 kV Line Fault (not needed if Weston 4 Net Generation ≤ 525 MW
^ - 60% ATC Loading OK if W31 out of service, ^^ - 80% ATC Loading OK if W31 out of service
ATC Loading: 100% = 13,932 MW, 80% = 11,146 MW, 60% = 8,359 MW
[1] - 500 MW if W31 out of service, [2] - 450 MW if W31 out of service

# IV. System Protection Criteria and Design

The design of the interim Weston 4 tripping scheme logic is derived from the stability simulations summarized in Table 3, but required compromise between effectiveness and simplicity. A simple design is more reliable, maintainable and, for the short period of transmission line construction, adds little risk of incorrectly tripping Weston 4. A more complicated scheme could minimize the number of Weston 4 tripping events, but would be more difficult to implement, would probably require increased human intervention to arm and disarm, and would be more prone to misoperation. If this scheme was being designed for a longer term system condition, a more complicated scheme would have been devised. Unusual or prolonged system outages during this interim period may increase or decrease the need to trip Weston 4. To allow for this, the protection scheme was designed with the ability to adjust generator tripping arm/disarm functions to be consistent with these unusual or prolonged conditions.

Two different Weston 4 Tripping Schemes will be implemented after unit testing begins near the end of December 2007. The first scheme (Figure 4) will be used until the Arrowhead-Stone Lake 345 kV line goes into service (May 2008). The second scheme (Figure 5) will be used from the time the Arrowhead-Stone Lake line goes into service until the Gardner Park-Highway 22 345 kV line goes into service (December 2009). As a conservative assumption, the Kelly-Whitcomb 115 kV line is assumed to be out of service during both of these periods, although it may be in service for part of the later period. No Weston 4 tripping scheme is necessary after the Arrowhead and Highway 22 lines are in service.

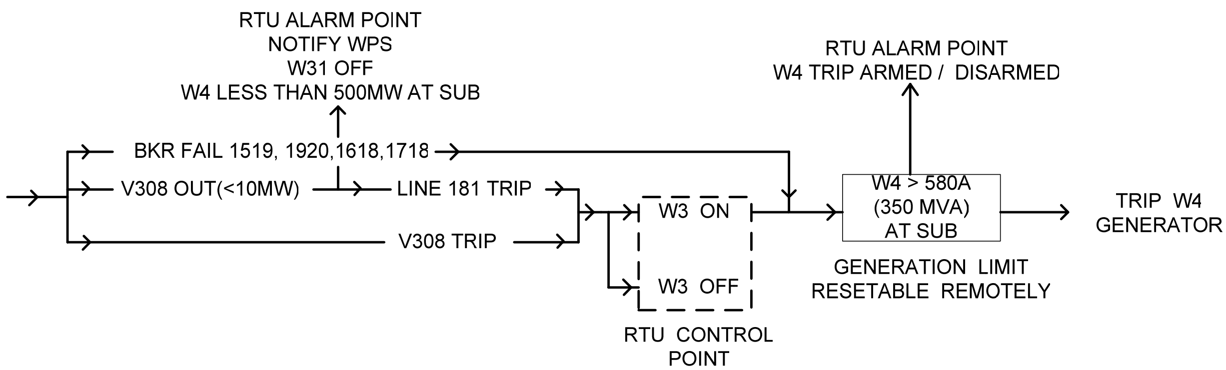


**Figure 4: Weston 4 Tripping Scheme Prior to Arrowhead-Stone Lake 345 kV Line in Service.**

The first Weston 4 tripping scheme is required prior to the Arrowhead-Stone Lake 345 kV line going into service (Figure 4) and reflects the need to trip Weston 4 more often under this weaker system condition than after Arrowhead-Stone Lake goes into service. For this first scheme, Weston 4 tripping is armed if the current on the short 345 kV line connecting Weston 4 to the Gardner Park 345 kV bus is greater than 580A. This reflects the simulation result that Weston 4 tripping is unnecessary under all breaker failure and prior outage conditions if unit generation is less than 350 MW (net). Although Weston 4 is a base load unit, rarely operating much below its maximum output, the time period when this scheme will be implemented lies entirely within the Unit testing period, when the unit will be operated at a variety of output levels. As seen in Table 3, unit tripping is unnecessary even at generation levels above 350 MW under some system conditions, particularly if Generator 31 is out of service. During SPS design the complexity added by automatically implementing tripping at different generation levels was determined to excessively impact scheme reliability, so it was not included in the scheme. The scheme does, however, allow manually adjusting the generation limit remotely. An RTU (Remote Terminal Unit) point that indicates whether or not the tripping circuit is armed is also included in the scheme.

The first tripping scheme provides that under intact system conditions failure of Gardner Park 345 kV breaker 1519, 1920, 1618, or 1718 will trip Weston 4 if tripping is armed as previously described (generation greater than 350 MW). Simulations determined that no unit outages, other than Weston 4, or system loading levels equal to or greater than 100% make tripping Weston 4 unnecessary. Simulations also showed that Weston 4 generation has to be less than 350 MW, as designed in the scheme, for unit tripping to be avoided. The only event that will trip Weston 4 for which simulations determined that it was not necessary to trip the unit is breaker 1718 failure during a fault on Transformer #1, rather than during a Gardner Park-Stone Lake line fault, which does require tripping Weston 4.

When the Gardner Park-Rocky Run line (V-308) is out of service, as determined by a monitored flow of less than 10 MW on the line, a fault on the 115 kV Weston-Rocky Run (T-20) or 345 kV Stone Lake-Gardner Park (GDP181) line could result in generator instability. Because the protection scheme is not set up to monitor faults other than 345 kV faults on lines connecting to the Gardner Park 345 kV bus, an RTU alarm point was set up to notify WPS when V-308 is out of service. When this occurs, Weston 31 must be off line and Weston 4 net generation must be less than 500 MW. This will prevent a T-20 fault from resulting in generator instability. The protection scheme will trip Weston 4 for a GDP181 fault, unless Weston 3 is out of service or Weston 4 generation is less than 350 MW. The scheme includes an operator controlled RTU point where W3 (Weston 3) ON (Weston 4 tripping enabled) or W3 OFF (Weston 4 tripping disabled) is selected. Tripping Weston 4 is also not necessary under this condition if Weston Units 2 and 31 are out of service, but this was not included in the protection scheme to minimize complexity.

A fault on V-308 (Gardner Park-Rocky Run 345 kV) will lead to generator instability if T-20 (Weston – Rocky Run 115 kV) line or GDP181 (Gardner Park–Stone Lake 345 kV) is out of service. Because the protection scheme is not set up to monitor the outages of 115 kV lines, such as T-20, which is not even connected to Gardner Park, the implemented protection scheme trips Weston 4 for all V-308 faults, whether the system is intact or under prior outage conditions, as long as Weston 3 is in service and Weston 4 generation is greater than 350 MW. Based on past history and the time this scheme is expected to be in service, there is an approximately 4% chance that there will be a V-308 fault during the time this scheme is in service.

While not major, there were several compromises made between simulation results and the first Weston 4 tripping scheme. These compromises are conservative in that they always trip Weston 4 when it is necessary to prevent generator instability, but sometimes trip the unit when it may not be necessary. This was done to maximize scheme reliability and maintainability with the knowledge that the scheme would only implemented for approximately six months. The second tripping scheme (Figure 5) is expected to be in service for approximately 18 months, so fever compromises were acceptable.

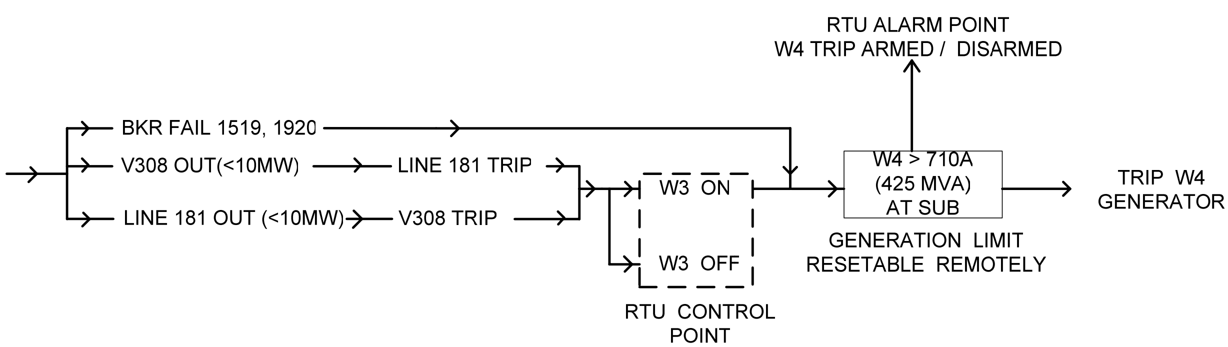


**Figure 5: Weston 4 Tripping Scheme Prior to Highway 22 345 kV Lines in Service.**

Like the first tripping scheme, the second tripping scheme, which is used after the Arrowhead line is in service, but before the Highway 22 line is in service, arms Weston 4 tripping only if Weston 4 net generator is above a certain level. For the second scheme this level is 425 MW, 75 MW greater than the first scheme. Weston 4 is a base load unit that is expected to operate near its maximum output of approximately 550 MW most of the time this scheme is in service. Although unit tripping is unnecessary at generation levels above 425 MW under a few system conditions, once again implementing tripping at different generation levels was determined to negatively impact scheme reliability and it was not implemented. The scheme does, as in the first tripping scheme, allow manually adjusting the generation limit remotely and includes an RTU point that indicates whether the tripping circuit is armed.

This second tripping scheme provides that under intact system conditions failure of Gardner Park 345 kV breaker 1519 or 1920 for faults on the Gardner Park-Rocky Run 345 kV line or Transformer #2 will trip Weston 4 if tripping is armed as previously described (Weston 4 net generation greater than or equal to 425 MW). Simulations determined that no unit outages, other than Weston 4, or system loading levels equal to or greater than 100% make tripping Weston 4 unnecessary. This scheme not will trip Weston 4 for any events that were not determined to require tripping by the simulations.

A fault on either V-308 (Gardner Park-Rocky Run) or GDP181 (Stone Lake-Gardner Park) with the other line out of service could result in generator instability. The scheme will trip Weston 4 for either of these conditions, unless Weston 3 is out of service or Weston 4 generation is less than 425 MW. As in the first scheme, this scheme includes an operator controlled RTU point where W3 ON (Weston 4 tripping enabled) or W3 OFF (Weston 4 tripping disabled) is selected. Tripping Weston 4 is also not necessary for a GDP181 fault with V-309 out of service if Weston Units 2 and 31 are out of service, but, once again, this was not included in the protection scheme.

## V. Conclusion

ATC has designed and is implementing a Special Protection System that will allow Weston 4 to maximize power output under intact and prior outage conditions for the interim periods before the completion of the Arrowhead-Stone Lake and Gardner Park-Highway 22 345 kV lines, which were determined to be required upgrades by generator interconnection studies. The schemes require tripping Weston 4 for specified faults while preventing multiple other units from losing synchronism. The temporary schemes required compromises to ensure that the tripping logic is reliable and maintainable. In no case will Weston 4 remain in service when tripping it is required to maintain system stability. However, in some cases, to keep the protection logic manageable, the unit may be tripped when studies have not identified this requirement. More compromises were designed in the first scheme, which will be in service for less than six months, than in the second scheme, which will be in service for approximately a year and a half.

# APPENDIX

## Table A-1 Notes

**Colors**

| Color | Meaning |
|---|---|
| Green | No Generators Trip |
| Yellow | Only Weston 31 Trips |
| Red | Unit(s) Other Than Weston 31 Trips |

**Tripped Units:** W1 or 1-Weston 1, W2 or 2-Weston 2, W3 or 3-Weston 3, W4 or 4-Weston4, W31 or 31-Weston 31, W32 or 32-Weston 32, W-Multiple Weston Units, WL-Multiple Weston and "Loop" Units, Wau-Wausau, OK-No Units

**Years:** 2007 – Pre-Arrowhead-Stone Lake, 2008 – Pre-Gardner Park-Highway 22

**CCT:** Critical Clearing Time (cycles)

**Filenames/Outages:** BFI-Breaker Failure with IPO Breaker, FLT-Primary Clearing Time Fault, X1 or XF1-Gardner Park 345/115 kV Transformer #1, X2 or XF2-Gardner Park 345/115 kV Transformer #2, ARR-Arrowhead, GPK-Gardner Park, RRN-Rocky Run, SLK-Stone Lake, WES-Weston

## Table A-2 Notes

2007 - Stone Lake-Arrowhead and Highway 22 Lines Not in Service
2008 - Highway 22 Lines Not in Service

*Gardner Park-Rocky Run 345 kV line Fault
**Gardner Park-Rocky Run or Gardner Park Xformer #2 Fault
***Gardner Park-Stone Lake 345 kV line Fault (not needed if Weston 4 ≤ 525 MW)

^ - 60% ATC Loading OK if W31 out of service.
^^ - 70% ATC Loading OK if W31 out of service.
^^^ - 80% ATC Loading OK if W31 out of service.
ATC Loading (MW): 100% = 13932, 90% = 12539, 80% = 11146, 70% = 9752, 60% = 8359

Notes: [1] - 550 MW if W31 out of service
[2] - 525 MW if W31 out of service
[3] - 500 MW if W31 out of service
[4] - 475 MW if W31 out of service
[5] - 450 MW if W31 out of service

# Table A-1: Stability Simulation Results Summary.

| Intact System | | | | | | | | Unit(s) Out | | | | | | | Weston 4 Generation (MW Net, Gross 50 MW more) | | | | | | | | ATC Loading | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| File | Prior Outage | BF Outage | Year | CCT | All In | Trip W4 | SLGF | W1 | W2 | W3 | W4 | W31 | W32 | 31&32 | 525 | 500 | 475 | 450 | 425 | 400 | 375 | 350 | 60% | 70% | 80% | 90% | 100% |
| BFIGPKRRN | none | X2 | 2007 | 4.5/9.5 | WL | OK | WL | WL | WL | W, Wau | OK | WL | WL | WL | | | | | WL | OK | OK | OK | WL | WL | WL | WL | WL |
| BFIGPKRRNx | none | none | 2007 | 4.5/9.5 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | | | W2, 31 | OK | | | WL | WL | WL | WL | WL |
| BFIGPKXF2 | none | RRN | 2007 | 4.5/9.5 | WL | OK | WL | WL | WL | W, Wau | OK | WL | WL | WL | | | | WL | OK | OK | | | WL | WL | WL | WL | OK |
| BFIDGPKRRN | none | X2 | 2007 | 7.5/11.0 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | WL | WL | OK | OK | OK | | | | WL | WL | OK | OK | OK |
| BFIDGPKRRNx | none | none | 2007 | 7.5/11.0 | WL | OK | OK | WL | WL | WL | OK | WL | WL | WL | WL | OK | OK | | | OK | | | WL | WL | OK | OK | OK |
| FLTGPKRRN | GPK-SLK 345 | N/A | 2007 | 4.5 | WL | OK | OK | OK | OK | OK | OK | WL | OK | OK | W31 | OK | OK | | | | | | OK | OK | OK | OK | OK |
| FLTWESRRN | GPK-RRN 345 | N/A | 2007 | 4.5 | W31 | OK | W31 | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | W31 | OK | OK | OK | OK |
| FLTGPKRRN | WES-RRN 115 | N/A | 2007 | 4.5 | WL | OK | OK | W31 | OK | OK | OK | WL | W31 | OK | W31 | W31 | W31 | OK | | | | | W31 | W31 | OK | OK | OK |
| BFIGPKRRN | none | X2 | 2008 | 4.5/9.5 | WL | OK | W, Wau | W, Wau | W, Wau | W2,4 | OK | WL | W, Wau | WL | | | W2,4,31 | OK | OK | | | | WL | WL | WL | OK | OK |
| BFIGPKRRNx | none | none | 2008 | 4.5/9.5 | WL | OK | WL | WL | WL | W, Wau | OK | WL | WL | WL | WL | WL | OK | OK | | | | | WL | WL | WL | OK | OK |
| BFIGPKXF2 | none | RRN | 2008 | 4.5/9.5 | WL | OK | W2,4,31 | W, Wau | W4 | W2,4 | OK | W, Wau | W, Wau | W2,4,Wau | WL | W2,4,Wau | OK | OK | | | | | WL | W2,4,31 | OK | OK | OK |
| FLTGPKRRN | GPK-ARR 345 | N/A | 2008 | 4.5 | W31 | OK | OK | OK | OK | OK | OK | OK | OK | OK | W31 | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK |

| F110 Out | | | | | | | | Unit(s) Out | | | | | | | Weston 4 Generation (MW Net, Gross 50 MW more) | | | | | | | | ATC Loading | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| File | Prior Outage | BF Outage | Year | CCT | All In | Trip W4 | SLGF | W1 | W2 | W3 | W4 | W31 | W32 | 31&32 | 525 | 500 | 475 | 450 | 425 | 400 | 375 | 350 | 60% | 70% | 80% | 90% | 100% |
| BFIGPKARR | none | X1 | 2007 | 4.5/9.5 | W4 | OK | OK | W4 | OK | OK | OK | OK | OK | OK | OK | OK | OK | | | | | | OK | OK | OK | OK | OK |
| BFIGPKRRN | none | X2 | 2007 | 4.5/9.5 | WL | OK | WL | WL | WL | W, Wau | OK | WL | WL | WL | | | | | | WL | OK | | WL | WL | WL | WL | WL |
| BFIGPKRRNx | none | none | 2007 | 4.5/9.5 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | | | | WL | OK | | WL | WL | WL | WL | WL |
| BFIGPKXF2 | none | RRN | 2007 | 4.5/9.5 | WL | OK | WL | WL | WL | W, Wau | OK | WL | WL | WL | | | | | WL | OK | | | WL | WL | WL | WL | WL |
| BFIDGPKRRN | none | X2 | 2007 | 7.5/11.0 | WL | OK | WL | WL | WL | W, Wau | OK | WL | WL | WL | | | WL | W2, 31 | OK | | | | WL | WL | WL | OK | OK |
| BFIDGPKRRNx | none | none | 2007 | 7.5/11.0 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | WL | OK | OK | | OK | | WL | WL | WL | OK | OK |
| FLTGPKRRN | GPK-SLK 345 | N/A | 2007 | 4.5 | WL | OK | WL | WL | WL | OK | OK | WL | WL | WL | WL | WL | W31 | OK | | | | | WL | W31 | W31 | OK | OK |
| FLTGPKARR | GPK-RRN 345 | N/A | 2007 | 4.5 | W31 | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | | | | | | OK | OK | OK | OK | OK |
| FLTWESRRN | GPK-RRN 345 | N/A | 2007 | 4.5 | W31 | OK | OK | W31 | W31 | OK | OK | OK | W31 | OK | W31 | W31 | W31 | OK | | | | | W31 | W31 | W31 | W31 | W31 |
| FLTGPKRRN | WES-RRN 115 | N/A | 2007 | 4.5 | WL | OK | WL | WL | WL | OK | OK | WL | WL | WL | WL | WL | W31 | W31 | OK | | | | WL | W31 | W31 | W31 | W31 |
| BFIGPKRRN | none | X2 | 2008 | 4.5/9.5 | WL | OK | WL | WL | WL | W2,4 | OK | WL | WL | WL | | | WL | OK | | | | | WL | WL | WL | WL | OK |
| BFIGPKRRNx | none | none | 2008 | 4.5/9.5 | WL | OK | WL | WL | WL | W, Wau | OK | WL | WL | WL | | | WL | OK | | | | | WL | WL | WL | WL | OK |
| BFIGPKXF2 | none | RRN | 2008 | 4.5/9.5 | WL | OK | W, Wau | WL | W, Wau | W2,4,32 | OK | WL | WL | WL | WL | WL | OK | | | | | | WL | WL | OK | OK | OK |
| BFIDGPKRRN | none | X2 | 2008 | 7.5/11.0 | W, Wau | OK | OK | W2,4,31 | W4 | OK | OK | W2,4,Wau | W2,4,31 | W2, 4 | OK | OK | OK | | | | | | OK | OK | OK | OK | OK |
| BFIDGPKRRNx | none | none | 2008 | 7.5/11.0 | W, Wau | OK | OK | W, Wau | OK | OK | OK | W2,4,Wau | OK | W2 | OK | OK | OK | OK | | | | | OK | OK | OK | OK | OK |
| FLTGPKRRN | GPK-ARR 345 | N/A | 2008 | 4.5 | WL | OK | OK | WL | WL | OK | OK | WL | WL | WL | WL | WL | W31 | OK | OK | OK | OK | OK | WL | W31 | W31 | OK | OK |
| FLTGPKARR | GPK-RRN 345 | N/A | 2008 | 4.5 | W31 | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | OK | | | | | | OK | OK | OK | OK | OK |

| J-36 Out | | | | | | | | Unit(s) Out | | | | | | | Weston 4 Generation (MW Net, Gross 50 MW more) | | | | | | | | ATC Loading | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| File | Prior Outage | BF Outage | Year | CCT | All In | Trip W4 | SLGF | W1 | W2 | W3 | W4 | W31 | W32 | 31&32 | 525 | 500 | 475 | 450 | 425 | 400 | 375 | 350 | 60% | 70% | 80% | 90% | 100% |
| BFIGPKARR | none | X1 | 2007 | 4.5/9.5 | W4 | OK | OK | W4 | OK | OK | OK | W4 | OK | OK | OK | OK | OK | OK | OK | | | | OK | OK | OK | OK | OK |
| BFIGPKARRx | none | none | 2007 | 4.5/9.5 | W4 | OK | OK | W4 | OK | OK | OK | W4 | OK | OK | OK | OK | OK | | | | | OK | OK | OK | OK | OK | OK |
| BFIGPKRRN | none | X2 | 2007 | 4.5/9.5 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | WL | WL | WL | WL | W2,31,Wau | OK | WL | WL | WL | WL | WL |
| BFIGPKRRNx | none | none | 2007 | 4.5/9.5 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | | | | | W2, 31 | OK | WL | WL | WL | WL | WL |
| BFIGPKXF2 | none | RRN | 2007 | 4.5/9.5 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | WL | WL | WL | W2, 31 | OK | | WL | WL | WL | WL | WL |
| BFIDGPKRRN | none | X2 | 2007 | 7.5/11.0 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | WL | WL | OK | | | | WL | WL | WL | OK | OK |
| BFIDGPKRRNx | none | none | 2007 | 7.5/11.0 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | WL | WL | OK | | | OK | WL | WL | WL | OK | OK |
| FLTGPKRRN | GPK-SLK 345 | N/A | 2007 | 4.5 | WL | OK | WL | WL | WL | OK | OK | WL | WL | WL | | | WL | W31 | OK | | | | WL | WL | W31 | W31 | W31 |
| FLTGPKARR | GPK-RRN 345 | N/A | 2007 | 4.5 | WL | OK | W31 | WL | W31 | OK | OK | WL | WL | WL | W31 | W31 | W31 | OK | OK | | | | W31 | W31 | W31 | W31 | W31 |
| FLTWESRRN | GPK-RRN 345 | N/A | 2007 | 4.5 | WL | OK | W31 | W31 | W31 | OK | OK | WL | W31 | OK | WL | W31 | W31 | W31 | W31 | W31 | W31 | OK | W31 | W31 | W31 | W31 | W31 |
| FLTGPKRRN | WES-RRN 115 | N/A | 2007 | 4.5 | WL | OK | WL | WL | WL | OK | OK | WL | WL | WL | | | WL | W31 | OK | | | | WL | WL | W31 | W31 | W31 |
| BFIGPKRRN | none | X2 | 2008 | 4.5/9.5 | WL | OK | WL | WL | WL | W2,4,Wau | OK | WL | WL | WL | | | WL | WL | OK | | | | WL | WL | WL | WL | OK |
| BFIGPKRRNx | none | none | 2008 | 4.5/9.5 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | | WL | OK | | | | WL | WL | WL | WL | OK |
| BFIGPKXF2 | none | RRN | 2008 | 4.5/9.5 | WL | OK | WL | WL | WL | WL | OK | WL | WL | WL | | | WL | OK | | | | | WL | WL | W31 | OK | OK |
| BFIDGPKRRN | none | X2 | 2008 | 7.5/11.0 | WL | OK | OK | WL | W4,31,Wau | OK | OK | WL | WL | WL | WL | OK | OK | OK | | | | | WL | OK | OK | OK | OK |
| BFIDGPKRRNx | none | none | 2008 | 7.5/11.0 | WL | OK | OK | WL | W4,31,Wau | OK | OK | WL | WL | WL | W2,31 | OK | OK | | OK | | | | W, Wau | OK | OK | OK | OK |
| FLTGPKRRN | GPK-ARR 345 | N/A | 2008 | 4.5 | WL | OK | WL | WL | WL | OK | OK | WL | WL | WL | WL | WL | OK | | | | | | WL | W31 | W31 | W31 | W31 |
| FLTGPKARR | GPK-RRN 345 | N/A | 2008 | 4.5 | WL | OK | W31 | WL | W31 | OK | OK | WL | WL | WL | WL | W31 | W31 | OK | | | | | W31 | W31 | W31 | W31 | OK |

**Table A-2: Actions or Conditions Necessary to Prevent Generator Instability.**

| Outage | Fixes | 2007 | 2007, F-110 | 2007, J-36 | 2008 | 2008, F-110 | 2008, J-36 |
|---|---|---|---|---|---|---|---|
| None | Trip W4 for BF | 1519*, 1920** | 1519*, 1920**, 1718*** | 1519*, 1920**, 1718***, 1618*** | 1519*, 1920** | 1519*, 1920** | 1519*, 1920** |
| | Unit Outages | W4 Out | W4 Out | W4 Out | W4 Out | W4 Out | W4 Out |
| | W4 Generation | ≤ 400 MW | ≤ 375 MW | ≤ 350 MW | ≤ 450 MW | ≤ 450 MW | ≤ 425 MW |
| | ATC Load ≥ | none (>100%) | none (>100%) | none (>100%) | 90% | 100% | 100% |
| GPK-SLK 345 (L-GDP181) | Trip W4 for | V-308 | V-308 | V-308 | | | |
| | Unit Outages | 1,2,3,4, or 32 | 3 or 4 | 3 or 4 | | | |
| | W4 Generation | ≤ 500 MW[2] | ≤ 450 MW[4] | ≤ 425 MW[5] | | | |
| | ATC Load ≥ | 60% | 90%^^ | none (>100%)^^^ | | | |
| GPK-ARR 345 | Trip W4 for | | | | V-308 | V-308 | V-308 |
| | Unit Outages | | | | 1,2,3,4,31 or 32 | 3 or 4 | 3 or 4 |
| | W4 Generation | | | | ≤ 500 MW[1] | ≤ 450 MW[4] | ≤ 475 MW |
| | ATC Load ≥ | | | | 60% | 90%^^ | none (>100%)^ |
| GPK-RRN 345 (V-308) | Trip W4 for | T-20 | GPK-ARR 345 or T-20 | GPK-ARR 345 or T-20 | | GPK-ARR 345 | GPK-ARR 345 |
| | Unit Outages | 1,2,3,4,31 or 32 | 3, 4, or 31 | 3, 4 or 2&31 | | 1,2,3,4,31 or 32 | 3, 4 or 2&31 |
| | W4 Generation | ≤ 525 MW[1] | ≤ 450 MW[1] | ≤ 350 MW[3] | | ≤ 525 MW[1] | ≤ 450 MW[3] |
| | ATC Load ≥ | 70% | none (>100%) | none (>100%)^ | | 60% | 100%^ |
| WES-RRN 115 (T-20) | Trip W4 for | V-308 | V-308 | V-308 | | | |
| | Unit Outages | 2,3,4,31&32 or 1&31 | 3 or 4 | 3 or 4 | | | |
| | W4 Generation | ≤ 450 MW[2] | ≤ 425 MW[4] | ≤ 425 MW[5] | | | |
| | ATC Load ≥ | 80%^ | none (>100%)^^ | none (>100%)^^^ | | | |