Western Farmers Electric Cooperative
System Impact Study Results for
Proposed 180 MW Facility

Prepared by
Martin L. Baughman (baughman@mail.utexas.edu)
W. Mack Grady (grady@mail.utexas.edu)

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Southwest Energy Associates, Inc.
5703 Painted Valley Drive
Austin, TX 78759
Tel (512) 345-8255
Fax (512) 345-9880

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Purpose

The purpose of this System Impact Study is to assess the transmission impacts of connecting the proposed Customer 180MW facility into Western Farmers Electric Cooperative's (WFEC) system. The proposed unit is scheduled to begin commercial operation February 2003. Results from loadflow, dynamic stability, and short circuit studies are presented.

Summary of Results

With no transmission improvements, initial loadflow studies identified two new elements that would overload under contingency conditions after the new generator is placed in service. These two elements were OG&E's 69KV line connecting Ada OC Pump to Ada OC Pump Tap and WFEC's 138-69KV transformer located at Franklin Switch. After the improvements needed for dynamic stability were added (see below), the Ada OC Pump problem disappeared, but one additional OG&E transmission element overloaded under contingency conditions after the new generator is placed in service. This new element is the138-69KV transformer at Paoli.

With no transmission improvements, stability studies revealed that the proposed generator would swing out of synchronism for any contingency that led to the loss of either the 138KV line extending between Pink and Pink Switch or the 138KV line extending between Pink Switch and Franklin. It was found necessary to connect an additional 138KV circuit from elsewhere in the system to the Pink 138KV substation for the new unit to maintain synchronism following a 5-cycle three-phase fault on one or another of the lines. At the suggestion of Mitch Williams of WFEC, this new circuit was routed from **Pink to the Canadian Switch 138KV substation**.

Short circuit studies revealed the largest increase in bus fault current occurs at the Pink 138KV bus as a result of adding the new generator there. In response to a three-phase fault the bus fault current at Pink increases from 5,981 to 13,138 Amperes per phase, an increase of 120 percent, as a result of adding the new generator there. Short circuit currents one bus away at the Canadian Switch, Franklin, United Clay, and Wewoka 138KV buses increase at most 25 percent in response to three-phase faults at these locations. Short circuit current two buses away from Pink increase by 24 percent at OG&E's 138KV Canadian bus, while the fault currents at all other two levels away from Pink increase by at most 5 percent. At three levels away from Pink the bus fault currents increase by at most 12 percent. Since, according to Mitch Williams of WFEC existing breakers in the area possess interrupting ratings of either 30,000 Amperes or 50,000 Amperes, in no case are the increases sufficient to require upgrading breakers.

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Study Methodology and Data

All studies were performed using PTI PSS/E software. Loadflow and dynamic stability analyses were performed for three cases, a base case before the addition of the proposed new unit and for two cases with the proposed new 180MW unit in service. In the first of the two additional cases it was assumed that the output from the new unit displaced existing generation at WFEC's Mooreland generating station. In the second case it was assumed that WFEC load increased by 180MW--using the load scaling feature of PSS/E--and the added load absorbed the output of the proposed new unit. Short circuit studies were performed first for a case without the new generator, then for a case with the new generator connected.

Loadflow Methodology and Data: Loadflow studies were performed to identify any new thermal loading or voltage problems that might be created by the addition of the new generating facility. The analysis included the examination of the effects that transmission outages would have on the line and transformer loadings in the area. The flows on all elements in SPP were monitored. Considered were all single outages of elements in the WFEC and OKGE systems, plus zones 201-206 and zone 210 of the AEP system-- altogether 1,402 single elements. Also considered was a set of 30 multiple outage contingencies in SPP and/or SERC that were provided by the SPP engineering staff.

All loadflow studies were performed on modified data for 2004 summer peak from a case labeled 04SP_GEN-00-15.SAV provided to the authors by Charles Hendrix of SPP.

Dynamic Stability Methodology and Data: Dynamic stability analyses were performed to assess whether the system would return to a stable and secure operating condition following critical disturbances in the neighborhood of the proposed new unit. Disturbances analyzed involved three-phase faults on one or another of the lines emanating from Pink 138KV bus, followed by a trip of the line.

The dynamic stability studies were performed using data for 2002 summer peak from a case labeled 02SP_TBIRD-STAB.SAV and associated dynamic data again provided to the authors by Charles Hendrix of SPP

Short Circuit Study Methodology and Data: Short circuit studies were performed to assess whether the ratings of the existing breakers are sufficient to interrupt the new short-circuit currents that would be experienced in the neighborhood of the proposed new generating unit if it were installed. These analyses were performed using the Automatic Short Circuit Calculation (ASCC) capability of PSS/E. The data used were for 2002 from a case labeled SC02-26 that was downloaded from the engineering ftp website at SPP.

Load Flow Study Results

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Contingency studies were first performed for a case with no new transmission improvements to accommodate the proposed new generating unit. These analyses presented two new thermal overloads in the various contingency cases. The first one was relieved after the stability improvements were added. The second new overloaded element remained even after the stability improvements. That element, and the contingency creating that overload, was:

Overloaded Element No. 1: Post-Contingency Flow of 110.8 Percent of "B" Rating on
WFEC Transformer From Bus 55916 [FRNKLNS269.0] To Bus 55917 [FRNKLNS138] Ckt 1
Contingency Creating this Overload:
Open WFEC Line From Bus 55917 [FRNKLNS4 138] To Bus 55975 [LIDDEL4 138] Ckt 1

After performing the stability studies described in the next section, it was discovered that a new 138KV circuit needs to be connected to the Pink substation for stability purposes. The contingency studies were repeated after a new line was added connecting Pink to Canadian Switch. Analyses of contingencies in this new configuration revealed one more overloaded element. The new overloaded element and the contingency creating the overload is:

Overloaded Element No.2: Post-Contingency Flow of 101.0 Percent of "B" Rating on
OG&E Transformer From Bus 55099 [PAOLI 2 69.0] To Bus 55100 [PAOLI 4 138] Ckt 1
Contingency Creating this Overload:
Open OG&E Line From Bus 55113 [CHIGLEY2 69.0] To Bus 55114 [CHIGLEY4 138] Ckt 1

No other new thermal overloads nor any new voltage problems were detected anywhere in SPP in the cases analyzed as a result of adding the new generation.

Stability Study Results

The results of three PSSE stability runs are designed to show the dynamic response of the system following critical disturbances in the neighborhood of the proposed new generator. The disturbances analyzed are 5-cycle three-phase faults on branches near the 138KV Pink bus followed by trips of the faulted branches. The three attachments are PSSE plots of the rotor angles of selected generators as a function of time in response to the disturbances. Shown are the angles of the proposed new Unit and other generators in WFEC and nearby systems.

If no transmission improvements are made, simulations show the proposed new unit will quickly overspeed if the Pink Switch to Franklin 138KV line is taken out-of-service for any reason, even if there is no fault. Double-circuiting the Pink to Pink Switch line does not solve the problem. Attachment D shows the response of the rotor angles of the monitored generators to a 5-cycle three-phase fault on the Pink Switch to Franklin 138KV line followed by a trip of the line after adding a second circuit between Pink and Pink Switch. The new unit still quickly overspeeds and swings out of synchronism.

To remedy the stability problem Mitch Williams of WFEC suggested that a new line, or new lines, be connected from Pink to elsewhere in the system to provide tighter electrical

connections between the generator and the rest of the system. He proposed adding first a 15-mile 138KV line from Pink to Canadian Switch, or alternatively a 30-mile 138KV line from Pink to Paoli, or both if necessary to provide adequate stability.

First we examined what would happen if just the shorter line to Canadian Switch were added. In this configuration the new unit showed a stable response to the fault at Pink Switch followed by loss of the Pink Switch to Franklin line (which was unstable above). But, in this configuration, more serious stability threats will likely be created by faults on either of the lines connected directly to the Pink 138KV bus. Attachments E and F show the system response to faults on these two lines, respectively.

Attachment E shows the response of the rotor angles to a 5-cycle three-phase fault on the Pink to Pink Switch line followed by a trip of the line. It can be seen that the Thunderbird Unit No. 3 oscillates, but quickly returns to a new stable equilibrium. Attachment F shows the response of the rotor angles to a 5-cycle three-phase fault on the other line (i.e., the Pink-Canadian Switch 138KV line). Review of the plots on the attachment shows this case is also stable.

As a result, it was concluded that only the addition of the Pink to Canadian Switch line is needed for stability purposes. It was also determined that 6 cycles is the critical clearing time for a three-phase at Pink in this configuration.

Short Circuit Study Results

The Automatic Short Circuit Calculation (ASCC) capability of PSS/E was used to calculate the short-circuit currents at buses in the neighborhood of the proposed new generator, before and after adding the new generator.

The table the bus fault currents at Proposed plant, then at buses 1, 2, and 3 levels away from Proposed plant. The results show that the further away one moves from the site of the new generator, the lesser is the impact of the new generator on the change in bus fault current. All current flows in the table are expressed in per unit and Amperes.

The largest increase in bus fault current occurs at Pink. Installing the new generator there causes the 3-phase fault current at Pink to increase by 120 percent, from 5,981 to 13,138 Amperes per phase. One bus away the largest increase occurs at Canadian Switch, an increase from 12,991 to 16,168 Amperes per phase. Two levels the largest increase occurs at OG&E's Canadian bus, an increase from 13,166 to 16,306 Amperes per phase. At three levels away the largest increase is 12 percent at OG&E's Cedar Lane bus, where the increase is from 17,117 to 19,243 Amperes per phase.

Since, according to Mitch Williams of WFEC, existing breakers in the area possess interrupting ratings of either 30,000 Amperes or 50,000 Amperes, in no case are the increases sufficient to require upgrading circuit breakers.

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		Fault Current Before Proposed Added			Fault Current After Proposed Added		Percent Increase
Bus No.	Bus Name	p.u.	Amperes		p.u.	Amperes	
56020	[PINK4 138]	14.3	5,981		35.5	13,138	120%
55838	[CANAD4 138]*	31.1	12,991		38.7	16,168	24%
55923	[FRNKL4 138]	51.0	21,322		54.5	22,661	6%
56073	[UNCLY4 138]	10.6	4,435		13.1	5,390	22%
56093	[WEWOK4 138]	12.1	5,077		14.7	6,033	19%
54807	[CANDN4 138]*	31.5	13,166		39.1	16,308	24%
54842	[MDWST4 138]	62.0	25,918		65.2	27,156	5%
55839	[CANADM]*	12.1	10,151		12.7	10,595	4%
55924	[FRNKLM]	10.7	8,948		10.8	9,060	1%
56018	[PHARO4 138]	35.0	14,642		35.9	14,988	2%
56058	[SUNSH4 138]	16.6	6,950		16.8	7,017	1%
52792	[WELEET 138]	36.6	15,323		37.5	15,654	2%
54022	[LOAK 4 138]	12.7	5,327		12.8	5,342	0%
54953	[DRAPR4 138]	80.0	33,488		82.4	34,430	3%
54974	[HOLWD4 138]*	64.4	26,927		67.0	27,971	4%
54977	[CDRLN4 138]*	40.9	17,117		46.1	19,243	12%
55811	[ANAWF4 138]	41.4	17,324		41.5	17,350	0%
96137	[BRIST4 138]	15.2	6,363		15.2	6,376	0%

* The buses marked with asterisks are one, two, or three levels away from Pink after the two new line to Canadian Switch is added. Before addition of this new line the marked buses are all more than three levels away from Pink.