System Impact Study For >Omitted Text<

Prepared by:

Wei-Jen Lee, Ph.D., PE
Professor of Electrical Engineering

Chai Chompoo-Inwai
Graduate Research Associate

Energy Systems Research Center
The University of Texas at Arlington
UTA Box 19048
Arlington, TX 76019

February 24, 2003

Purpose

The purpose of this System Impact Study is to assess the transmission impacts of connecting the 120 MW. >Omitted Text< wind project into Western Farmers Electric Cooperative's (WFEC) system near Hammon, OK. This wind farm will be connected to the WFEC transmission system via a new switching station near Elk city, OK (Attachment A). The proposed unit is scheduled to begin commercial operation in 2005. Load flow, short circuit, and dynamic stability analysis are performed in this study.

Study Methodology and Data

PTI PSS/E software is used to perform the study. Load flow, and dynamic stability analyses were performed for two cases, a base case before the addition of the proposed >Omitted Text< wind project and for the another case with the proposed new 120 MW generation in service. In the later case, it was assumed that the output from the new unit displaced existing generation at WFEC Mooreland generating station. Short circuit studies were performed first for a case without the new generator, then for a case with the new generator connected.

Load flow Methodology and Data:

All load flow studies were performed on modified data for 2005 summer peak from the case labeled TS05SP02.SAV. In all cases it was assumed that all >OMITTED TEXT< units were in service, connected to WFEC 138KV bus between MOREWOOD (WFEC), and ELK CITY (PSO), and operated at full power output.

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 2005 from the file labeled B05SP4.SEQ that was downloaded from the engineering ftp website 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 severe disturbances in the neighborhood of the proposed new units. Disturbances analyzed involved 5 cycles three-phase faults on one or another of the bus emanating from the new generator bus, followed by a trip of the line.

New Generator Location and Line Flows

A schematic is included as Attachment B showing the configuration and steady state power flows in the neighborhood of the WFEC, and PSO area prior to the addition of the proposed new generating unit. Detail on the schematic is all the connections to the 138KV substations and the flows on the connecting branches.

Attachment C shows the same schematic but after the new 120MW generating unit is added with. This schematic shows the flows at the same substations Attachment B but for the case in which the output of the plant is used to displace existing generation at Mooreland.

If one compares the flows on Attachment C with those on Attachment B, it can be seen that 113 MW, or almost a hundred percent of the output of the new generating unit, flows toward to bus no.54121 [ELKCTY-4 138] located at ELK CITY.

Load Flow Study Results

The feasibility study investigated the effect of the new generation on system performance during normal and contingency conditions. The steady state contingency analysis considers the impact for the new generation on transmission facility loading and transmission bus voltage for outages of transmission line, autotransformers, and generators. The steady-state analysis considered the impact of a 120 MW transfer on transmission line loadings in the local area of the wind farm. The latest version of Southwest Power Pool 2005 summer peak base case was used for this study.

Single contingency analysis was performed for the >Omitted Text< project. That analysis indicated that the addition of the 120 MW of generation creates the potential for a slight overload on the Morewood 138/69-kV transformer (which has a 50 MVA emergency rating) and a high loading on the Elk City-Morewood 138-kV circuit (with a rating of 150 MVA). To avoid overloading situation at steady state, the output of the wind farm is lower down to 114 MW in further studies. The Attachments C through E show the power flow results for the wind farm to be operated at 0.95 leading, unity, and 0.95 lagging, respectively. Considering the worst case scenario, the result of the 0.95 leading is used in the further analysis.

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.

Following below shows the bus fault currents at the neighborhood main generators bus in WFEC area. All current flows in the list are expressed in amperes.

The largest increase in bus fault current occurs at bus no. 54121[ELKCTY-4 138]. Installation the new generator at bus 50004 causes the 3-phase fault current at bus no. 54121 to increase by 18.85 percent, from 6,370.1 to 7571.1 amperes per phase. One more significant increasing of fault current locates at bus no.56001 [MORWODS4 138]. The 13.2 percent increasing of fault current affected by the new generator was observed.

```
A. The original system’s base case: current fault at interested-bus
      PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E THU, FEB 13 2003   0:01
 1-2001 SOUTHWEST POWER POOL POWER FLOW BASE CASE   SHORT CIRCUIT
 2005 SUMMER PEAK (TS05S2), TRANSIENT STABILITY MODEL
                            FAULT CURRENTS
                         OUTPUT FOR AREA 525 [WFEC    ]
                            THREE PHASE FAULT
 ------ AT BUS ------           /I+/    AN(I+)
 55811 [ANADRK4 13.8] AMPS   46280.7  -106.56
 55812 [ANADRK5 13.8] AMPS   46332.6  -106.16
 55813 [ANADRK6 13.8] AMPS   46277.5  -106.16
 55814 [ANADARK4 138] AMPS   16637.7   -98.35
 55947 [HUGO1   23.4] AMPS   81465.2   -85.79
 55948 [HUGO PP4 138] AMPS   13150.2   -87.52
 55996 [MORLND1 13.8] AMPS   35867.8   -96.89
 55997 [MORLND2 18.0] AMPS   66186.2   -96.28
 55998 [MORLND3 18.0] AMPS   65662.4   -96.33
 55999 [MOORLND4 138] AMPS   10626.1   -93.58
 56001 [MORWODS4 138] AMPS    4182.8   -94.27
 54121 [ELKCTY-4 138] AMPS    6370.1   -94.50
```

B. After add new wind generator at bus 50004: current fault at interested-bus

------ AT BUS ------		/I+/	AN(I+)	%increase(compare with base case)
55811 [ANADRK4 13.8]	AMPS	46308.9	-104.57	+0.06%
55812 [ANADRK5 13.8]	AMPS	46360.9	-104.12	+0.06%
55813 [ANADRK6 13.8]	AMPS	46305.7	-104.12	+0.06%
55814 [ANADARK4 138]	AMPS	16723.0	-96.40	+0.52%
55947 [HUGO1 23.4]	AMPS	81463.2	-85.76	-0.002%
55948 [HUGO PP4 138]	AMPS	13157.2	-87.50	+0.05%
55996 [MORLND1 13.8]	AMPS	35920.2	-93.27	+0.15%
55997 [MORLND2 18.0]	AMPS	66408.8	-92.69	+0.33%
55998 [MORLND3 18.0]	AMPS	65884.6	-92.75	+0.33%
55999 [MOORLND4 138]	AMPS	10750.6	-90.09	+1.20%
56001 [MORWODS4 138]	AMPS	4735.1	-89.55	+13.2%
54121 [ELKCTY-4 138]	AMPS	7571.1	-91.05	+18.85%
50000 [ELK_MORE 138]	AMPS	6751.6	-91.41	new bus in the system
50004 [TRANGEN 13.8]	AMPS	58531.1	-93.09	new generator bus in the system

Stability Study Results

In this study, stability analysis was performed to determine the possible stability problems that can be caused by the new wind generation. The transmission line model used in this study was the SPP system model for the 2005 summer peak conditions. Stability studies were achieved using the Power System Analysis Program (PSS/E, version 28). The summer peak 2005 transmission line model was used as a based-case condition which comparisons would be made. Then, various system configurations, and faults were added to the original system to determine the stability effect of the new wind generation to original system.

The results of four PSS/E stability analyses are shown in Attachments F. Various cases study are designed to show the dynamic response of the system following critical disturbances in the neighborhood of the proposed new generator. The disturbances analyzed were based on 5-cycle three-phase faults on different buses near the new wind generator followed by removing the fault through tripping the line. The 29 studied cases of Attachments F are PSSE plots of the power output of selected generators in the WFEC area as a function of time in response to the disturbances.

Simulations have shown that if the wind generator is operated at 0.95 leading (worst case scenario), the terminal at >Omitted Text< unit (at bus 50004) will develop under-voltage problems when the line between the new switching substation (at bus 50000) and Elk city station (at bus 54121) is taken out-of-service. To remedy this problem, ESRC suggested the following three improvement strategies that can solve the stability problem of the system:

- ?? Operate the new proposed generator at 0.95 lagging power factor instead of operated that unit at 0.95 leading power factor.
- ?? Install under voltage relay at the new generator bus. This under-voltage relay will trip the new unit of wind generator when its terminal voltage drops down to the setting value. Thirty-cycle delay of the under-voltage relay is implemented in the study to avoid immediate tripping of the unit during faults.
- ?? Perform transfer trip to drop at least 10 MW from the wind farm when trips the line between the new switching substation (at bus 50000) and Elk city station (at bus 54121).

Case Model descriptions:

Case1: Base case

- The SPP summer peak'2005 model was used as a base case.
- There is no new generator added to the system.

Case2xxx-Case8xxx: Studied cases

- The SPP summer peak'2005 model was used as a base case.
- A new 114 MW wind powered-generation is added to the original system.
- The various abnormal system conditions were studied to investigate how much the new wind-generator affects the stability of the system.

Case9xxx: Methods to remedy the stability problem caused by new wind generator

Note: All of the simulation results here show the output-power of the different plants in SPP's system. Main generators at the following bus are monitored:

- bus no.50004 : the new wind-generator bus (>Omitted Text< wind Project)
- bus no.55811,55812 : ANADRK4
- bus no.55812 : ANADRK
- bus no.55947 : HUGO1
- bus no.55996,55997 : MORLND
- bus no.53712 : WELSH3

Summary of Results

Without the addition of new facilities and/or the replacement of existing facilities, the result from power flow analysis shows that the addition of the >Omitted Text< wind generation causes slight overload on the local WFEC system. Therefore, the total output of wind farm would be limited to 114 MW instead of operates at full load capacity (120 MW).

Short circuit studies revealed the largest increase in bus fault current occurs at the Elk city 138-kV (at bus no. 54121) as a result of adding the new generator at bus 50004. In response to a three-phase fault, the bus fault current at Elk city increases from 6,370 to 7,571 Amperes per phase (18.5% increase).

Stability studies have revealed possible stability issues when any contingency that led to the loss of the 138KV line between the new wind farm substation (at bus 50000) and Elk city (at bus 54121). To remedy this stability problem, three solutions of facilities improvement were proposed.