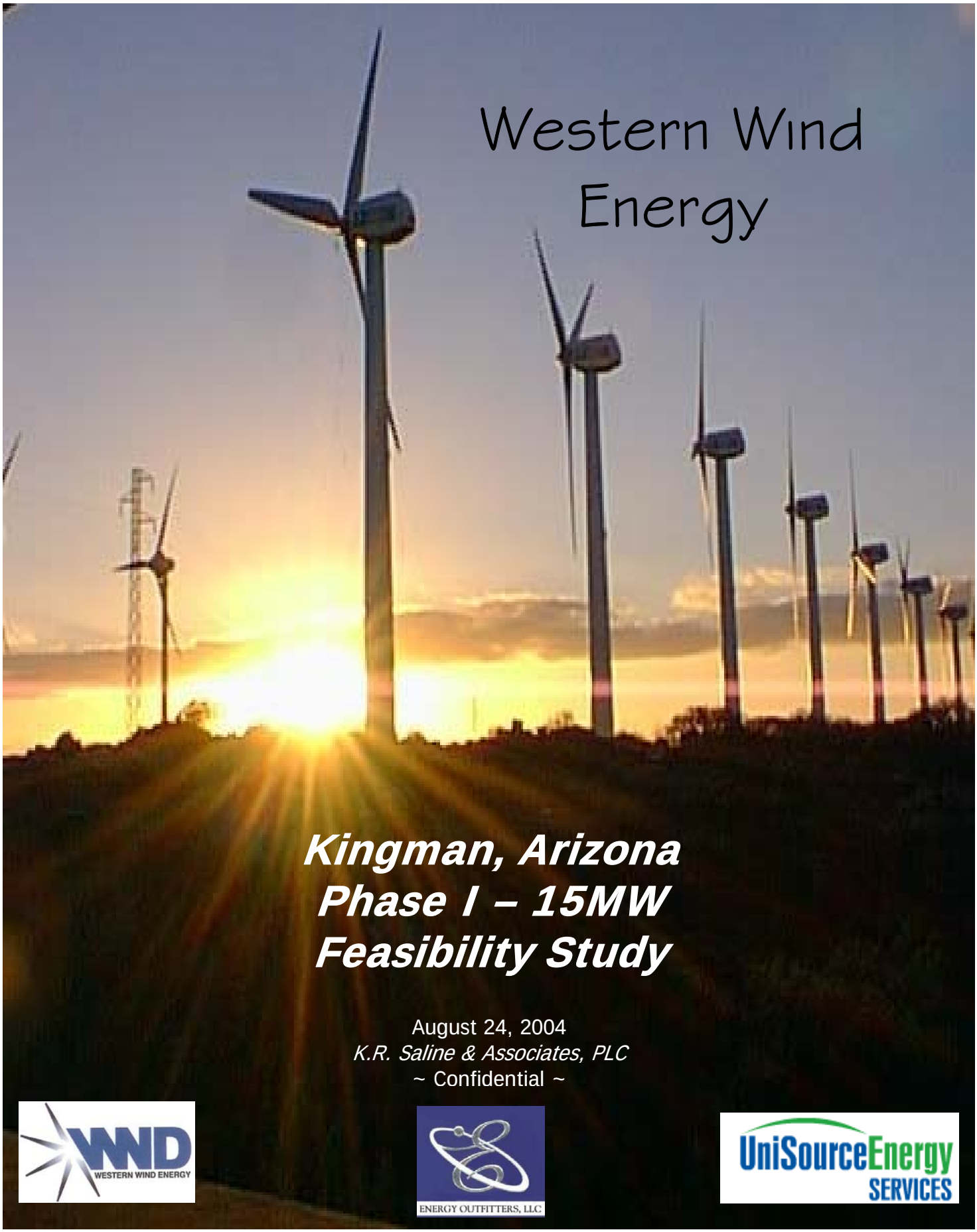

Western Wind Energy

Kingman, Arizona
Phase I – 15MW
Feasibility Study

August 24, 2004

K.R. Saline & Associates, PLC

~ Confidential ~

EXECUTIVE SUMMARY

Based on the results of this power flow feasibility analysis, the addition of 15MW of wind generation to the Dolan Springs 69kV system near Kingman, Arizona may be interconnected with little impact to the Kingman area regional system.

This feasibility study found that:

- The addition of 15MW wind generation to the Dolan Springs 69kV substation did not cause facility overloads pre or post contingency.
- With the addition of the generation near the end of the radial 69kV system, the voltage profile along the line is significantly improved due to the existing conductors and length along the radial 69kV system.
- With the addition of the generation and loss of the step-up transformer at the Dolan Springs substation, this analysis (both on-peak and off-peak) determined that approximately a 7.5% voltage drop would occur at the Dolan Springs substation. This voltage drop did not fall below a magnitude of 0.95 p.u.
- With the addition of the generation, the 69kV losses were reduced along the 69kV line in the on-peak analysis, however the off-peak losses were slightly higher (due to the lighter loading along line segments further north towards Pierce Ferry).
- With the addition of the generation near the end of the radial 69kV line, any outage along this line will require a transfer-trip mechanism to take the turbines off-line and prevent feeding an “islanded” system.
- The existing 1/0 copper segment from the North Kingman tap region to Pierce Ferry has a capacity of approximately 37MVA, and is the limiting element for incremental load north of the Kingman tap or additional wind generation (estimated to be near 30MW total).

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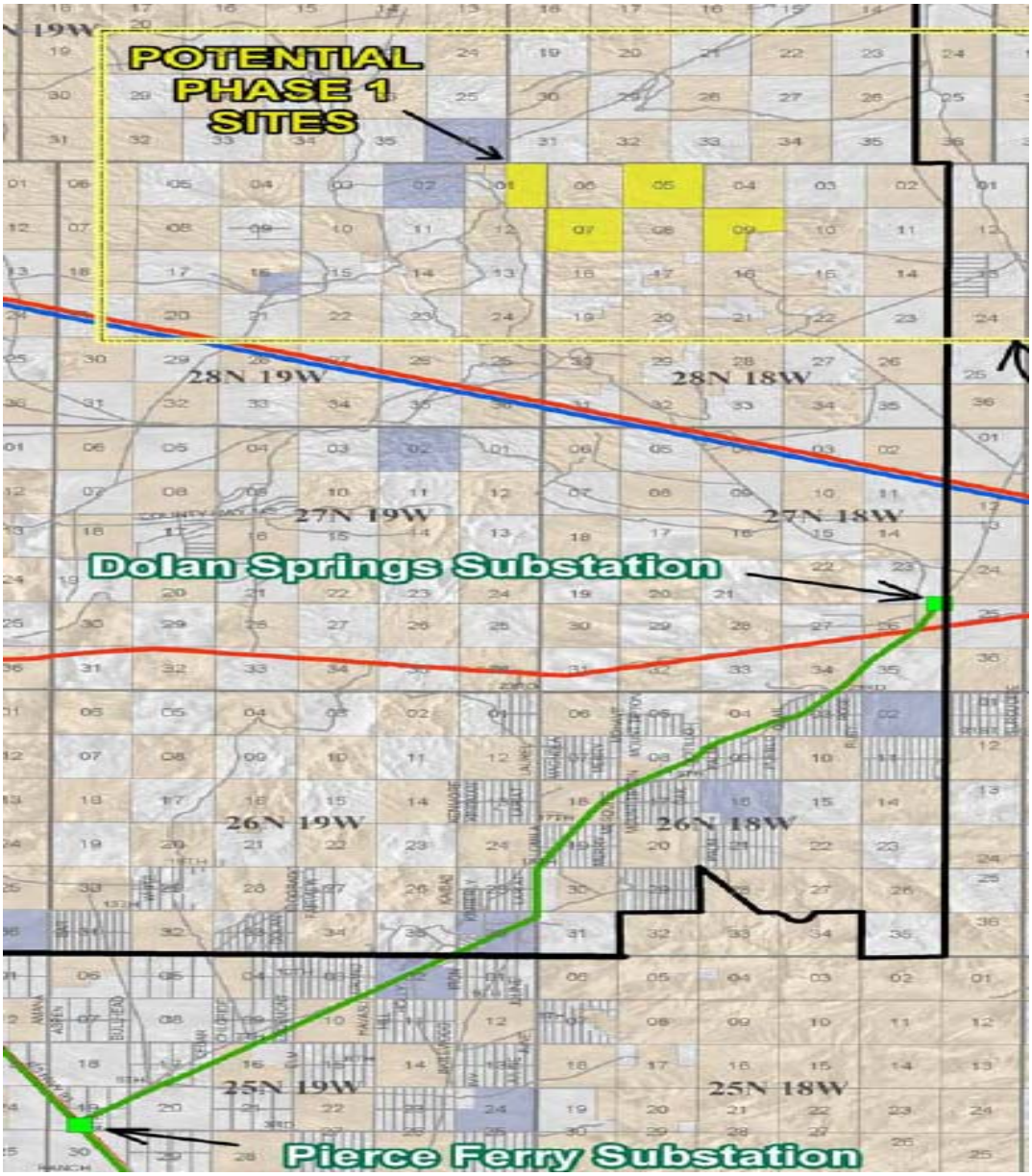
INTRODUCTION

Western Wind Energy ("Western Wind") requested an interconnection to the Dolan Springs 69kV system for 15MW of wind generation. The purpose of this feasibility study was to review the impact of interconnecting 15MW of wind generation (Phase I) to the UniSource Energy Service ("UES") 69kV system near Kingman, Arizona. Ultimately, in Phases II and III, Western Wind may connect up to 400MW of wind energy to the interconnected transmission system near Kingman, Arizona (including additional wind generation connected directly to the UES 69kV system). This study documents the power flow impacts to the system of the 15MW interconnected at Dolan Springs substation for a 2005 Heavy Summer and 2005 Light Autumn time frame.



STUDY METHODOLOGY

UES provided the Heavy Summer 2006 and Light Autumn 2005 WECC bulk cases for this analysis. The detailed 69kV model from Griffith to Dolan Springs and Gold Strike substations were added to the bulk cases. The detailed 69kV line lengths and conductor information was provided by UES in AutoCAD format and converted to PSLF values using the ASPEN line constants program. Detailed conductor parameters can be located in Appendix C.

Loads and power factor were adjusted for loads in the region per UES. Arizona's internal generation offset both the load changes in the pre and post project cases and the addition of the Western Wind generation in the post project cases.

As a feasibility study, only the connection of the generator and its impact on voltage, flow, and overloads was reviewed. Pre and post project cases were developed to identify the impact due to the turbine. A limited contingency analysis was performed for elements in the study region. Both short circuit and stability analysis will be performed as part of the final system impact study.

STUDY ASSUMPTIONS

The starting cases provided by UES from WECC were assumed accurate, and then modified to include the detailed 69kV model, expected loads, and typical power factor of loads in the region.

Modeling Assumptions:

- Transformer models for load serving transformers and step-up transformer for the turbine were estimated and do not represent the actual transformers.
- The addition of the 15MW wind turbine was offset with a reduction of APS West Phoenix generation
- Loads are non-coincident peak loads, showing worst case loads
    - Peak (summer) load for the radial system was 128MW
    - Off Peak (autumn) load for the radial system was 35% of peak, or approximately 45MW.
- Conductor information and lengths provided were accurate

Contingency Analysis Assumptions:

- Review limited to area 14 (Arizona) busses
- Voltage deviation greater than 5% as well as voltage less than .95 or greater than 1.05 p.u. were flagged with contingencies.
- Loadings on elements greater than or equal to 90% of normal rating pre and post contingency were flagged.

This feasibility study does not review the stability or the short circuit impacts of the system pre or post project for either summer or autumn cases.

MODEL DETAILS

The Vestas wind turbines, which in reality will be approximately 9 turbines connected to a 34.5kV collector system with a step-up transformer to connect with the UES 69kV bus, was modeled as a single 15MW generator on a 34.5kV bus at Dolan Springs interconnected by a 7.5% impedance 34.5/69kV, 20MVA transformer.

The appendix contains additional modeling details, including lines modeled with associated line lengths, conductors and impedances.

The table below summarizes the load, generation, losses and flow changes in the cases.

	Summer (On Peak)			Autumn (Off Peak)		
	06WECC 06hs3sa1	**Pre Project**	**Post Project**	**05WECC 05LA1sa2**	**Pre Project**	**Post Project**
Loads (MW)						
Hilltop 230kV	94.9	76.4	76.4	58.4	26.7	26.7
Davis 230kV	4.2	4.8	4.8	1.4	1.7	1.7
Griffith 230kV	0	0	0	0	0	0
69kV Detail	0	47.7	47.7	0	16.7	16.7
Generation (MW)						
WW Generation	0	0	15	0	0	15
Flow (MW)						
Griffith 230/69kV	0	48.9	33.2	0	16.8	2.3
Losses (MW)						
Losses 69kV	0	1.2	.5	0	.1	.6

OPERATIONAL CONSIDERATIONS FOR A RADIAL SYSTEM

This study modeled 15MW of wind generation at the end of a long (>20mile) radial 69kV system. Due to the radial nature of the system, there are some special operating considerations that should be addressed:

- Transfer -Trip to the 34.5kV bus at Dolan Springs to isolate the generators in the event of an outage anywhere along the 69kV radial system from Griffith.
- Additional relaying and communications as required by UES and TEP as the control area operator for this 69kV system.
- Additional operating procedures as required by UES operations for safety, specific system operating conditions, visibility of the wind generation, and the energy that may flow into the Griffith 230kV system.
- Although Vestas has indicated that harmonics are minimal (reference Appendix I), a harmonics analysis should be conducted for this interconnection to determine if the potential for harmonics may be worsened for locating wind generation at the end of a long radial system.

POWER FLOW RESULTS

The following sections detail the results of power flow and contingency analysis.

2005 HEAVY SUMMER – ON PEAK

The findings related to the summer peak case include:

- Voltage improvement of nearly 6% with the generation; improved voltage profile.
- Low Voltage (0.945 p.u) at the Black Mesa 69kV bus with and without the generator.
- Voltage deviation greater than 5% occurred with the generation case at four 69kV busses due to the loss of the generator step-up transformer at Dolan Springs, Willow Beach, Gold Strike and Highway 69kV busses. The busses maintained voltage greater than 0.96 per unit.
- With the exception of the aforementioned busses, no element in the study area violated voltage or loading criteria pre or post contingency.
- Approximately 1MW reduction in losses along the Griffith-Dolan Springs 69kV line.
- Any outage along the radial 69kV line will require a transfer trip mechanism to take the turbines off-line to prevent the turbines feeding an "islanded" system".
- The 1/0 Copper 37MVA conductor from North Kingman to Dolan Springs may be a limiting element with continued load growth or generation construction.

2005 LIGHT AUTUMN – OFF PEAK

The findings related to the autumn off peak case include:

- No pre- or post contingency voltage violations in the study region without the turbine.
- Voltage violations, both pre contingency and delta voltage, with the generation for busses in the study region. Busses exceeded 1.05 per unit pre-contingency, and showed voltage deviation greater than 5% for loss of the Dolan Springs step up transformer, but remained above 1.0 per unit with the exception of the Pierce Ferry 69kV bus. The Pierce Ferry 69kV bus experienced a voltage drop of 6% and settled at 0.96 per unit post contingency with the turbine.
- No study area element was overloaded pre or post contingency with or without the project.
- Approximately .5MW increase in losses due to the VAR consumption of the 1/0 Copper conductor from North Kingman to Dolan Springs substation. The increase in losses was due to lighter loading along line segments beyond Pierce Ferry.
- Any outage along the radial 69kV line will require a transfer trip mechanism to take the turbines off-line to prevent the generation from feeding an "islanded" system".
- The power flow distribution of the 15MW showed that approximately 5MW was supplied to the Griffith 69kV bus, as opposed to the radial system receiving 9MW without the wind generation.
- The 1/0 Copper 37MVA conductor from North Kingman to Dolan Springs may be a limiting element with continued load growth or additional generation development.

POWER FLOW STUDY FINDINGS

Review of the outage reports and power flow maps found:

- The addition of 15MW wind generation to the Dolan Springs 69kV substation did not cause facility overloads pre or post contingency.
- With the addition of the generation near the end of the radial 69kV system, the voltage profile along the line is significantly improved due to the existing conductors and length along the radial 69kV system.
- With the addition of the generation and loss of the step-up transformer at the Dolan Springs substation, this analysis (both on-peak and off-peak) determined that approximately a 7.5% voltage drop would occur at the Dolan Springs substation. This voltage drop did not fall below a magnitude of 0.95 p.u.
- With the addition of the generation, the 69kV losses were reduced along the 69kV line in the on-peak analysis, however the off-peak losses were slightly higher (due to the lighter loading along line segments further north towards Pierce Ferry).
- With the addition of the generation near the end of the radial 69kV line, any outage along this line will require a transfer-trip mechanism to take the generation off-line and prevent feeding an “islanded” system.
- The existing 1/0 copper segment from the North Kingman tap region to Pierce Ferry has a capacity of approximately 37MVA, and is the limiting element for incremental load north of the Kingman tap or additional wind generation (estimated to be near 30MW total).

APPENDICES

Appendix A – Geographic System Map(s)

Appendix B – WECC Case information

Appendix C – Modeling Assumptions

Appendix D – Contingency List

Appendix E – On Peak – Pre Project Power Flow Results

Appendix F – On Peak – Post Project Power Flow Results

Appendix G – Off Peak – Pre Project Power Flow Results

Appendix H – Off Peak – Post Project Power Flow Results

Appendix I –Reference Data