# Analysis of Wind Power Integration in the Flint Hills Area of Kansas

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## 1. Introduction

For more than a century before 1997, Kansas was a net energy exporter. Because of declining oil and gas production, in 1997 Kansas became a net importer of energy. Kansas now imports about 55 percent of its energy from outside the state. Forecasts predict this number will increase over the next ten years. While renewable energy production, primarily in the form of wind generation and ethanol, is increasing in the state [1, 2, 3], it is not known when these resources will contribute a significant portion of the total energy production.

The U.S. Department of Energy ranks Kansas third nationally for wind energy potential. In spite of this, very little wind power has been developed in the state. The broad expanse of open plains and high ridges, together with lack of trees, urban areas, and large individual buildings makes Kansas an excellent site for wind energy. The total average wind potential of Kansas is estimated to be 121,900 MW, of which only 113.7 MW has been developed thus far [4, 5]. Some areas of the Flint Hills have high potential for wind energy, which coupled with the presence of high voltage (HV) power transmission lines and proximity to the two largest population centers makes this region attractive to the wind industry.

Because of government incentives and mature wind generation technology, installed wind generation capacity is growing rapidly and utilities are interested in its costs and effects on the power system. Integrating wind energy into the transmission grid has both technical and economical consequences. The effect of wind's intermittent nature on transmission and other generation needs to be determined and minimized.

## 2. Experiment, Result, Discussion, and Significance

Kansas has numerous sites suitable for wind generation. Previous studies show that western and southern Kansas contains Class IV and V wind areas. Data also indicates that southern portions of the Flint Hills may have average annual wind speeds in the Class V to VI range. No data has been collected for central portions of the Flint Hills, and data collected in the northern portions have been solely focused on the Tuttle Creek area. If Class V/VI data previously found in the southern Flint Hills are representative of other areas of the Flint Hills, the wind energy potential reported for the area may be significantly underestimated [4, 5, 6]. Among several feasible sites in this area, Gun Barrel, Teterville, and Beaumont were chosen for a more detailed study. Technical Details of these sites can be found in Table 1.1.

**TABLE 1.1**

**Wind Data and Transmission Access Summary of three sites**

| **Site Name** | **Estim. Wind Class** | **Wind Velocity** (Miles/Hour) | **Power Density** ($W/M^2$) | **Capacity Potential** (MW) | **Total Area** (Acres) | **Transmission Access** | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | **Voltage Level** (kV) | **Distance** (Miles) | **Owner** |
| Gun Barrel | III | 16.2 | 365 | 86 | 12,600 | 115 | 0-2 | Western Plains |
| | | | | | | 230 | 0-4 | Western Plains |
| Teterville | IV | 17.3 | 430 | 94 | 20,000 | 345 (2) | 2-8, 8-10 | Western Resources |
| | | | | | | 115 | 0-2 | Western Resources |
| Beaumont | IV | 16.9 | 390 | 127 | 23,600 | 138 | 8 | Western Resources |
| | | | | | | 345 | 3-5 | Western Resources |

A modified power flow study is used to analyze the effects of wind generation on the electric power grid. Data was taken from information that utilities and the Southwest Power Pool (SPP) filed with the Federal Energy Regulatory Commission (FERC) in 1999, in compliance with FERC Order 715. The model used was the SPP forecast for the 2005 summer peak. PowerWorld commercial power flow software was used for the simulation [7, 8].

***Incorporating Wind Generators into PowerWorld***

The output power of wind generators is variable with wind speed; therefore, either the load or the other generators in the system must be adjusted accordingly to accommodate this power fluctuation. PowerWorld assumes that generators are dispatchable. Since wind generators are not dispatachable, the power transaction concept (MW Transfer) was applied to incorporate wind generators in PowerWorld. This concept is normally used to implement a power purchase agreement between two areas for a particular time interval. In these simulations, scheduled transfers between wind generators and the utility represent wind fluctuations over a given time interval. The simulation is run for 24 hours, first without the wind generators and then with all three. For each hour, power flows, transmission line loading, load following generators, and transmission line voltages were analyzed.

## 3. Conclusions and Recommendations

The system model developed in this thesis added time-varying wind generation to the power flow model of a large generation and transmission system. This was implemented successfully in commercial power flow software. This methodology will allow studies of transmission line loading, changes in power flow, and voltage variations, as well as other related technical issues involving wind generators in the power system. This simulation can also be used to examine how conventional generator output and tie line flows change with variations in wind generation. In spite of the tremendous energy potential, interconnecting wind generators to a power system may create many unwanted consequences related to reliability, quality, and security of the power supply. These issues can be examined, analyzed and verified using this model. The study and analysis carried out here for the Flint Hills area of Kansas resulted in the following conclusions and recommendations.

- The power flow study shows no transmission overloads on the particular day chosen for simulation. This does not mean that overloads would not occur on other days; therefore this should be studied in the future.
- The system has other generators that adjust their outputs according to changes in wind power. Tie-line flows also change, and some of the wind power appears to be exported from the local area. The amount of power imported from other areas appears to be decreased significantly by the operation of wind generators. Since the changes in tie line flows do not equal the changes in wind generation, some of the generators inside the system must also be following the changes in the wind generation. These generators cannot be identified in this study, because they may be connected at lower voltages that do not appear in the SPP model used here.
- The effects caused by these wind generators are manageable and may be integrated successfully into the existing system.

***Future Work***

In addition to the power flow study presented in this thesis, contingency and fault analyses should be performed to ensure proper operation of the wind generators. Each site has various options for interconnection according to transmission voltage levels. Costs related to the different interconnection options should be analyzed. The study of tie-line flows and load-following is limited in this study. A further study of tie-line flows and generator-output variations is needed in the future.

## 4. References


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