BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

Application of Kansas City Power & Light Company for an Extension of Time to Comply with the Provision of its Regulatory Plan Stipulation and Agreement Concerning Wind Measuring Equipment in Missouri	)))))	Case No. EO-2006-0281

TALL TOWER PROJECT WIND STUDY STATUS REPORT

Pursuant to the order issued by the Missouri Public Service Commission ("Commission") on April 27, 2006 in the above-captioned proceeding and Section B.4 of the Stipulation and Agreement approved by the Commission in Case No. EO-2005-0329, Kansas City Power & Light Company ("KCPL") hereby respectfully provides its final status report analyzing eighteen months of wind study data from the Tall Towers Project. In support hereof, KCPL offers as follows:

1. On April 27, 2006, the Commission issued its Order Approving Application For Extension Of Time To Comply With Provisions Of Stipulation And Agreement Concerning Installation Of Wind Measuring Equipment ("April 27 Order"), which granted KCPL's request for an extension of time to complete the installation of certain wind measuring equipment and to provide twelve- and eighteen-month wind study data reports.

2. On September 28, 2007, KCPL provided the wind study report for the initial twelve-month test period of August 2006 through July 2007.

3. KCPL hereby provides the final wind study reports for the test period of August 2007 through January 2008. The progress reports are entitled *Tall Tower Investigations of Missouri Winds, Progress Report 6* (Schedule 1) and *Tall Tower Investigations of Missouri Winds, Progress Report 7* (Schedule 2). The reports are authored by Dr. Neil Fox with the

Department of Soil, Environmental and Atmospheric Studies at the University of Missouri – Columbia.

4. Data compiled through the Tall Towers Project was used in the screening of proposals for KCPL's contemplated 2008 wind addition. While Missouri wind sites appear feasible, Missouri wind project proposals provided a higher Net Present Value of Revenue Requirements than other project proposals. These results were presented in a Comprehensive Energy Plan Update meeting held on September 12, 2007 in Jefferson City.

5. KCPL is in discussion with the University of Missouri and the Missouri Department of Natural Resources to extend its support of the Tall Towers Project through June 30, 2008, allowing the Project to compile a full, two years of data. If agreed, KCPL will continue to monitor the data provided during this extension.

Respectfully submitted,

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Dated: March 28, 2008

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing comments were served via first class mail, postage pre-paid, on this 28th day of September 2007 upon each of the following parties of record:

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TALL TOWER INVESTIGATIONS OF MISSOURI WINDS

Progress report 6 – January 15th, 2008

General

The two towers operating under this project have now been collecting data for almost 18 months. In this report we detail the continued analysis of the observations and the performance of the instrumentation.

The tower instrumentation continues to operate well, although there were significant icing events during December 2007 that reduced the period for which good data was collected and put stress on the sensors. The Raytown tower cellphone connection operates well, so that this tower is not visited. Channel 3 on the Miami tower is still not recording good data and this problem can be seen in some of the data. This will be discussed later, but an adjustment to correct for the problem is being developed.

In general, however, and with experiences at other towers to draw on, it is apparent that a routine replacement of the anemometers by a tower crew should be performed in the coming months, if we wish to continue collecting good data.

Data

In tables 1 and 3 below are simple monthly means of wind speed recorded at each height on each of the towers. For the Miami tower there are two months (September and October 2007) when the middle height records lower mean speeds than both the upper and lower ones. This is very unlikely to be an accurate depiction of the winds, and is far more likely to be an error introduced by the failure of the north facing anemometer at this height. As the monthly means are calculated using the greater wind speed at each height every hour, if the remaining sensor is frequently sheltered by the tower itself then the mean will be lower than when both instrument records are available. In this case it appears that as winds become more northerly through the fall the wind sensor on the southern extended boom is sheltered more frequently and the wind does not appear as strong as it should be.

By comparing the wind speeds recorded by the two anemometers at the same height for each different wind direction recorded while both instruments are operational, it is possible to develop a correction to the recorded wind speed based on wind direction for a single anemometer that is sheltered (provided that a long enough record of simultaneous observation exists, as is the case here). However the sheltering effect appears to be very sensitive to the structure of the tower and positioning of the instruments. Therefore it is not possible to develop a general correction routine that can be applied universally, and each level on each tower must be considered individually with its own empirically derived adjustment.

In the second year of data collection the continued observations also allows us to compute rolling annual means to investigate whether there is any upward or downward trend that would be indicative of a changing wind regime. These rolling means are shown in tables 2 and 4. As the initial year's data revealed wind speeds lower than those indicated by the wind map it is important to see if there are noticeable changes seen in the evolving data set, but to date there has been little change and no clear trend in the rolling annual average. Some months have been windier than the equivalent months in the previous year (e.g. September and October), and others are less windy (e.g. November and December). The pattern appears consistent across towers.

Month	67 m	93 m	114 m
July 2006	5.17	5.77	5.36
August 2006	5.34	6.00	6.64
September 2006	5.70	6.28	6.77
October 2006	6.72	7.52	8.21
November 2006	6.74	7.53	8.04
December 2006	7.24	8.17	9.06
January 2007	6.89	7.53	8.23
February 2007	6.82	7.16	7.92
March 2007	7.83	8.18	9.46
April 2007	7.14	7.41	8.39
May 2007	5.99	5.76	7.21
June 2007	5.51	5.61	6.62
July 2007	5.03	5.46	6.38
August 2007	5.54	5.85	6.94
September 2007	5.93	5.61	7.17
October 2007	7.09	6.85	8.64
November 2007	6.54	6.87	7.93
December 2007	6.35	6.83	7.83

Table 1: Monthly average wind speed (in m s^{-1}) for height of the Miami tower.

12-month period	67 m	93 m	114 m
Year (Aug 06 – Jul 07)	6.41	6.90	7.73
Year (Aug 06 – Jul 07)	6.40	6.86	7.73
Year (Sep 06 – Aug 07)	6.41	6.85	7.75
Year (Oct 06 – Sep 07)	6.43	6.79	7.79
Year (Nov 06 – Oct 07)	6.46	6.73	7.82
Year (Dec 06 –Nov 07)	6.45	6.68	7.82
Year (Jan 07 – Dec 07)	6.38	6.57	7.71

Table 2: Rolling annual mean wind speeds (m s^{-1}) at the three heights of the Miami tower

Month	67m	93 m	142 m
August 2006	4.23	4.92	5.74
September 2006	4.71	5.50	6.34
October 2006	5.15	6.12	7.15
November 2006	5.11	6.16	7.35
December 2006	5.43	6.51	7.74

January 2007	5.90	6.68	7.28
February 2007	5.59	6.26	6.92
March 2007	5.89	6.78	7.62
April 2007	5.87	6.66	7.26
May 2007	4.69	5.64	6.45
June 2007	4.59	5.40	6.06
July 2007	4.05	4.84	5.48
August 2007	4.64	5.53	6.27
September 2007	4.65	5.60	6.59
October 2007	5.35	6.54	7.76
November 2007	4.83	5.58	5.58
December 2007	5.26	6.16	6.97

Table 3: Monthly average wind speed (in m s^{-1}) for each channel of the Raytown tower.

12-month period	**67 m**	**93 m**	**142 m**
Year (Aug 06 – Jul 07)	5.25	5.92	6.55
Year (Sep 06 – Aug 07)	5.30	5.99	6.62
Year (Oct 06 – Sep 07)	5.30	6.00	6.64
Year (Nov 06 – Oct 07)	5.31	6.03	6.70
Year (Dec 06 –Nov 07)	5.13	6.01	6.84
Year (Jan 07 – Dec 07)	5.09	5.96	6.76

Table 4: Rolling annual mean wind speeds (m s^{-1}) at the three heights of the Raytown tower

Annual records: Weibull Distributions

As there was disagreement between the observed wind speeds and those predicted by the wind map, a further test of the frequency distributions at each tower location was made using the first complete year of data collected. This involved fitting Weibull distributions to the observed frequency distribution of wind speeds and comparing the Weibull parameters to those presented by the wind map. As the wind map only provides values for the wind at 50m height, the recorded wind speeds were first adjusted to that height using a standard logarithmic wind profile.

A statistical analysis was used to determine the 95% confidence intervals for the c and K parameters of the Weibull distribution provided by the wind map and these were compared to those found for the data. Table 5 gives the values for the scale parameter (c), while table 6 gives the vales for the shape parameter (K). In each case it is shown that the parameters derived from the data fall outside the confidence intervals of the map data which indicates that the two follow different distributions. In the case of the scale parameter, this supports the prior finding that the mean wind speeds are significantly lower than those provided by the wind map. The difference in the shape parameter indicates that the frequency distribution of high and low winds is not the same as the map suggests. In particular, the increased values of K suggest that there is a more normal distribution of wind speeds than the map indicates, however part of this difference may be because of the use of hourly wind values, rather than 10-minute averages, which would naturally produce a narrower distribution of recorded wind speeds.

Tower	c from tower data	95% confidence intervals for c from wind map
Miami	6.95	6.85, 6.92
Raytown	5.71	6.51, 6.71

Table 5: Comparison of Weibull distribution scale parameters

Tower	K from tower data	95% confidence intervals for K from wind map
Miami	2.618	2.227, 2.411
Raytown	2.397	2.381, 2.382

Table 6: Comparison of Weibull distribution shape parameters.

A more detailed report on this work as it pertains to sites across the network supported by the different tall tower projects will be completed and distributed shortly

Future work

There are a number of investigations that are either ongoing or desirable using such a unique data set as has been collected and continues to be gathered. It is unlikely that within the framework of the current project that all of these will be explored to the depth that they could be. The common element in all these planned developments is the use of wind direction information, and a general move to the more detailed 10-minute average data.

1. Using 10-minute winds

To date little has been done using the 10-minute wind averages as almost all the analyses have used the hourly observations. However, to accurately assess the wind shear distribution, the tower sheltering effect and the variations of surface roughness with direction the shorter interval would be far better to use. On the other hand the size of the 10-minute data set makes its handling problematic, so that performing comparisons between the hourly and 10-minute data for sample periods may be the best way to gain the benefits of both.

2. Wind sheltering studies and corrections

As mentioned above some of the data suffers from sheltering effects of the wind. While for the two towers in this study this problem is manageable at the present time it is still desirable to develop corrections to assess the level of error for the middle level sensors on the Miami tower, and prepare for possible future equipment failures.

3. Detailed wind shear analysis

Little has been presented about the wind shear to date, but this is a critical aspect of wind resource assessment and wind farm planning. Initially we need to assess the wind shear frequency distribution prior to investigating the variation in shear with wind direction and low-level jet occurrence.

4. Wind speed and shear versus direction

At some point we intend to determine how the wind speed and shear are related to the wind direction. In a region like Missouri, where the topography is variable and the fetch can be sensitive to direction, investigating the impact of wind direction can allow a better assessment of how a proposed wind farm would operate under different weather conditions.

5. Analysis of low-level jet frequency and the variation of wind speed and shear under LLJ conditions

As the low-level jet is a frequent occurrence in this area, understanding how the wind conditions are affected by its presence is a critical element in this study. Identifying and categorizing low-level jet occurrence has been an ongoing part of the work we have undertaken, and this needs to be extended to determine how the status and characteristics of the jet impact the wind pattern at turbine height.

TALL TOWER INVESTIGATIONS OF MISSOURI WINDS

Progress report 7 – March 27th, 2008

General

The two towers operating under this project have now been collecting data for more than the 18 months mandated by the project requirements. The first tower at Miami, MO was instrumented on 30th June 2006, and the second, at Raytown, MO, on 25th July 2006. For the most part the tower instrumentation continues to operate well, such that a consistent data set has been collected for more than the initial 18 months specified. It remains beneficial to continue collecting data for as long as possible, as much can be gained from an extended period of data collection. The data included in this report continues until 24th March 2008.

A longer data record will allow us to address questions about the representative nature of the first 18 months of data, and more questions about the variation in wind speed and wind shear under a range of meteorological conditions. In general, however, and with experiences at other towers to draw on, it is apparent that a routine replacement of the anemometers by a tower crew should be performed in the coming months, if we wish to continue collecting good data.

In this document we report the continued analysis of the observations and the performance of the instrumentation. Due to time constraints the data presented herein for the first three months of 2008 should be considered preliminary, as thorough quality control of the data from this period has not been undertaken. There were a considerable number of icing incidents throughout these months and identifying all times of affected data is difficult. Also, the conditions appear to have taken a toll on the instrumentation at the Miami tower with an increasing number of errors appearing. It is suspected that a replacement data logger would be of value in maintaining reliable data collection at this time

Data

In tables 1 and 3 below are simple monthly means of wind speed recorded at each height on each of the towers. For the Miami tower there are two months (September and October 2007) when the middle height records lower mean speeds than both the upper and lower ones. This is very unlikely to be an accurate depiction of the winds, and is far more likely to be an error introduced by the failure of the north facing anemometer at this height. A correction procedure (discussed in the previous report) is currently being developed.

Rolling annual means are shown in tables 2 and 4. As the initial year's data revealed wind speeds lower than those indicated by the wind map it is important to see if there are noticeable changes seen in the evolving data set, however there is little evidence of any trend in this data as yet.

Month	67 m	93 m	114 m
July 2006	5.17	5.77	5.36
August 2006	5.34	6.00	6.64
September 2006	5.70	6.28	6.77
October 2006	6.72	7.52	8.21
November 2006	6.74	7.53	8.04
December 2006	7.24	8.17	9.06
January 2007	6.89	7.53	8.23
February 2007	6.82	7.16	7.92
March 2007	7.83	8.18	9.46
April 2007	7.14	7.41	8.39
May 2007	5.99	5.76	7.21
June 2007	5.51	5.61	6.62
July 2007	5.03	5.46	6.38
August 2007	5.54	5.85	6.94
September 2007	5.93	5.61	7.17
October 2007	7.09	6.85	8.64
November 2007	6.54	6.87	7.93
December 2007	6.35	6.83	7.83
January 2008	7.67	8.22	9.19
February 2008	6.29	6.74	7.28
March 2008	6.23	6.68	7.18

Table 1: Monthly average wind speed (in m s^{-1}) for height of the Miami tower.

12-month period	67 m	93 m	114 m
Year (Jul 06 – Jun 07)	6.41	6.90	7.73
Year (Aug 06 – Jul 07)	6.40	6.86	7.73
Year (Sep 06 – Aug 07)	6.41	6.85	7.75
Year (Oct 06 – Sep 07)	6.43	6.79	7.79
Year (Nov 06 – Oct 07)	6.46	6.73	7.82
Year (Dec 06 –Nov 07)	6.45	6.68	7.82
Year (Jan 07 – Dec 07)	6.38	6.57	7.71
Year (Feb 07 – Jan 08)	6.44	6.63	7.80
Year (Mar 07 – Feb 08)	6.41	6.59	7.77
Year (Apr 07 – Mar 08)	6.28	6.46	7.59

Table 2: Rolling annual mean wind speeds (m s^{-1}) at the three heights of the Miami tower

Month	67m	93 m	142 m
August 2006	4.23	4.92	5.74
September 2006	4.71	5.50	6.34
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October 2007	5.35	6.54	7.76
November 2007	4.83	5.58	5.58
December 2007	5.26	6.16	6.97
January 2008	5.99	6.92	7.85
February 2008	5.62	6.24	6.80
March 2008	5.47	6.23	7.04

Table 3: Monthly average wind speed (in m s^{-1}) for each channel of the Raytown tower.

12-month period	67 m	93 m	142 m
Year (Aug 06 – Jul 07)	5.25	5.92	6.55
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Year (Nov 06 – Oct 07)	5.31	6.03	6.70
Year (Dec 06 –Nov 07)	5.13	6.01	6.84
Year (Jan 07 – Dec 07)	5.09	5.96	6.76
Year (Feb 07 – Jan 08)	5.11	5.99	6.82
Year (Mar 07 – Feb 08)	5.11	5.98	6.81
Year (Apr 07 – Mar 08)	5.06	5.93	6.75

Table 4: Rolling annual mean wind speeds (m s^{-1}) at the three heights of the Raytown tower

Future work

There are a number of investigations that are either ongoing or desirable using such a unique data set as has been collected and continues to be gathered. It is unlikely that within the framework of the current project that all of these will be explored to the depth that they could be, and a no-cost extension has been requested to allow the further development of these investigations at no additional cost to the sponsor. This will align this work with the schedules of the other related tall tower investigations that have also been extended. Much of the work benefits greatly from the intercomparison of data collected at the different tower sites and coherence between the different projects means that each individual study is enhanced.

Most of the studies described below are already underway.

1. Using 10-minute winds

To date little has been done using the 10-minute wind averages as almost all the analyses have used the hourly observations. However, to accurately assess the wind shear distribution, the tower sheltering effect and the variations of surface roughness with direction the shorter interval would be far better to use. On the other hand the size of the 10-minute data set makes its handling problematic, so that performing comparisons between the hourly and 10-minute data for sample periods may be the best way to gain the benefits of both.

2. Wind sheltering studies and corrections

As mentioned above some of the data suffers from sheltering effects of the wind. While for the two towers in this study this problem is manageable at the present time it is still desirable to develop corrections to assess the level of error for the middle level sensors on the Miami tower, and prepare for possible future equipment failures.

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Little has been presented about the wind shear to date, but this is a critical aspect of wind resource assessment and wind farm planning. Initially we need to assess the wind shear frequency distribution prior to investigating the variation in shear with wind direction and low-level jet occurrence.

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At some point we intend to determine how the wind speed and shear are related to the wind direction. In a region like Missouri, where the topography is variable and the fetch can be sensitive to direction, investigating the impact of wind direction can allow a better assessment of how a proposed wind farm would operate under different weather conditions.

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As the low-level jet is a frequent occurrence in this area, understanding how the wind conditions are affected by its presence is a critical element in this study. Identifying and categorizing low-level jet occurrence has been an ongoing part of the work we have undertaken, and this needs to be extended to determine how the status and characteristics of the jet impact the wind pattern at turbine height.