The Liberty Consulting Group
65 Main Street
P O Box 237
Quentin PA 17083
(717) 270-4500



December 22, 2004

Kentucky Public Service Commission
Attn: John A. Rogness, III, Manager
Management Audit Branch
211 Sower Blvd.
Frankfort, Kentucky 40601-8294

Dear Mr. Rogness:

The Liberty Consulting Group *(Liberty)* is pleased to submit the attached report to The Kentucky Public Service Commission *(the Commission)*. This report provides the results of Liberty's review of the application of Big Rivers Electric Corporation for a Certificate of Public Convenience and Necessity to construct a 161 kV transmission line, Case No. 2004-00365.

The focus of Liberty's review was Big Rivers' analysis of the need for and engineering aspects of the proposed high voltage transmission line. Liberty found that Big Rivers needs the proposed 161 kV transmission line, and that Big Rivers performed the appropriate system studies and analyses to justify the need for the proposed line.

Liberty appreciates the opportunity to work with the Commission on a project of this importance.

Sincerely,

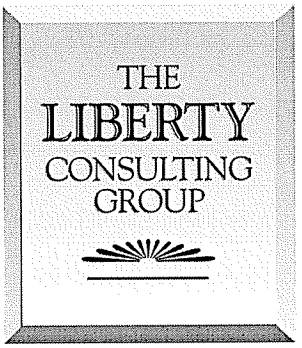
Robert L. Stright
Executive Vice-President

# Final Report
# Focused Review of Documentation
# Filed by Big Rivers Electric Corporation
# For a Proposed 161 kV Transmission Line
# Within Kentucky
# Case No. 2004-00365

Presented to:

## The Kentucky Public Service Commission

By:




65 Main Street
Quentin, Pennsylvania 17083

(717) 270-4500 (voice)
(717) 270-0555 (facsimile)
Admin@LibertyConsultingGroup.com (e-mail)

December 22, 2004

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# Executive Summary

## A. Purpose and Scope of this Report

### 1. Background

Pursuant to KRS 278.255, the Kentucky Public Service Commission (*Commission* or *KPSC*), employed The Liberty Consulting Group (*Liberty*) to perform a Need Review of documentation associated with a 161 kilovolt (kV) transmission line proposed for construction by Big Rivers Electric Corporation (*Big Rivers*).

Liberty is a management and technical consulting firm that specializes in the public-utility industries. Liberty has extensive experience in conducting focused reviews of this type. Liberty has served commissions in thirty-five different states and the District of Columbia in conducting focused reviews and management audits similar to this work related to the Big Rivers transmission project.

This report provides the results of Liberty's review of the application of Big Rivers for a Certificate of Public Convenience and Necessity (*Certificate*) to construct a 161 kV transmission line.

### 2. Project Scope and Objectives

The overall objective of this project was to review Big Rivers' efforts regarding the "need" for and engineering aspects of the proposed high voltage transmission line. The proposed line will be located in Breckinridge and Meade Counties, Kentucky. It will be approximately 17 miles long, and located as described in detail in Section B.1 below. Included in this report is an independent evaluation of Big Rivers' analyses and conclusions in support of the reasonableness of the need for the proposed transmission line.

This project was a focused review. Liberty reviewed Big Rivers' work but did not produce an independent transmission study. However, this report does encompass all the issues relevant to the need for the additional transmission line. An evaluation of the overall cost of the proposed line was not part of the scope of work for this project.

Liberty's work focused on the following aspects of the Need Review:

1. Review the utility's analysis of the ability of existing facilities to reliably serve existing and expected load, including the utility's power flow analyses and stability analyses.
2. Review and evaluate the analyses that support the utility's need for the proposed transmission line. The evaluation should include, but not be limited to, whether adequate consideration was given to:
   a. The upgrade of existing lines or facilities and transmission routes, and
   b. Other alternatives, including the use of generation and power factor improvement, and

c. Whether wheeling power through neighboring systems to the north or east of Big Rivers or through interconnections with the Louisville Gas and Electric Company (*LG&E*) would be a viable alternative to construction of the proposed new transmission line.

# B. Project Overview

## 1. Project Description

Big Rivers owns generating assets and purchases, transmits, and sells electricity at wholesale. Its principal purpose is to provide the wholesale electricity requirements of its three distribution cooperatives: Kenergy Corporation, Meade County Rural Electric Cooperative Corporation (Meade County RECC), and Jackson Purchase Energy Corporation. The distribution cooperatives in turn provide retail electric service to approximately 101,000 consumer/members located in 22 western Kentucky counties: Ballard, Breckinridge, Caldwell, Carlisle, Crittenden, Daviess, Graves, Grayson, Hancock, Hardin, Henderson, Hopkins, Livingston, Lyon, Marshall, McCracken, McLean, Meade, Muhlenberg, Ohio, Union, and Webster.[1] Meade County CC provides retail electrical service to Breckinridge County, the majority of Meade County, and small portions of Ohio and Grayson Counties.[2]

On October 25, 2004, Big Rivers filed an application with the Commission to construct a 161 kV line that is more than one mile in length. The Commission assigned the application Case No. 2004-00365.[3]

The proposed 161 kV line will tap the existing Skillman to New Hardinsburg 161 kV line at a point approximately three miles west of the New Hardinsburg substation in central Breckenridge County and extends approximately 17.3 miles in a generally northeasterly direction to the Big Rivers Meade County substation in southwestern Meade County. The proposed 161 kV line will supply Meade County RECC and function to provide the second feed to the Meade County substation.[4] The Meade County substation in turn serves approximately 9,800 retail customers through seven Mead County RECC distribution substations.[5] The existing Skillman to New Hardinsburg 161 kV circuit will be opened at Hardinsburg, effectively creating a Skillman to Meade County to New Hardinsburg 161 kV loop feed for the Meade County substation.[6] Meade County RECC only has direct electrical connections with Big Rivers. The projected cost of the proposed facilities is $3.3 million.[7]

[1] October 25, 2004 application of Big Rivers, paragraph 2.
[2] KPSC Electric Service Areas in Kentucky map dated May 6, 2003.
[3] October 25, 2004 application of Big Rivers, paragraph 1.
[4] October 25, 2004 application of Big Rivers, paragraph 6.
[5] October 25, 2004 application of Big Rivers, paragraph 16.
[6] Big Rivers Transmission System Construction Work Plan, 2003-2005, page 7, dated July 2002.
[7] October 25, 2004 application of Big Rivers, paragraph 8.

## 2. Summary of Liberty's Work

Liberty performed its independent Need Review by breaking the project down into two main Task Areas, as follows: [8]

### Task Area One – Technical Need Review

To determine if the proposed facilities were required from a technical viewpoint, Liberty reviewed Big Rivers' analyses, including its power flow analysis and long range plans, of the existing 161 kV and 69 kV facilities to determine whether they would reliably serve the existing and expected load in Meade County RECC.

### Task Area Two – Alternatives

To determine if the Big Rivers' analyses properly considered appropriate engineering alternatives to meet its needs, Liberty's evaluation considered whether Big Rivers gave adequate consideration to:

a. The upgrade of existing lines or facilities and transmission routes,
b. Other alternatives, including the use of generation and power factor improvement, and
c. Whether wheeling power through neighboring systems to the north or east of Big Rivers or through interconnections with the Louisville Gas and Electric Company would be a viable alternative to construction of the proposed new transmission line.

*Review Process*

Liberty reviewed Big Rivers' filed application, Big Rivers' 2000-2002 and 2003-2005 Transmission Construction Work Plans, Big Rivers' 2001 and 2003 Load Forecasts, and Big Rivers' Draft 2002 Transmission System Long Range Plan for 2006-2017. In addition, Liberty conducted extensive on-site interviews in Henderson Kentucky on November 22-23, 2004, with Big Rivers' subject-matter experts as listed below:

William C. Yearly - Manager Resources and Market Systems
Ralph A. Ashworth - Manager of Accounting
David G. Crockett - Manager Engineering and Operations
Christopher S. Bradley - Senior Planning Engineer

[8] Liberty Work Plan dated December 9, 2004.

## C. Conclusion Summary

On the basis of materials reviewed, interviews conducted, and the above, Liberty makes the following conclusions:

1. Big Rivers needs the construction of its proposed New Hardinsburg to Meade County 161 kV transmission line to meet the electric service requirements of Meade County RECC.

2. Big Rivers performed the appropriate system studies and analyses to justify the need for the proposed 161 kV transmission line.

# I. Technical Need Review

### *Scope*

This chapter addresses the following topics:

- Reliability Criteria
- Thermal Ratings
- Fault Analysis
- Load Forecasting
- Technical Analysis.

### *Background*

This chapter of Liberty's report presents the results of Liberty's review of Big Rivers' analysis of the ability of existing 161 kV and 69 kV facilities to reliably serve existing and expected load in the Meade County area of Kentucky. The review included a review of Big Rivers' power flow analyses, long-range plans, and stability analyses. In this chapter, Liberty also provides the results of its assessment of the proposed transmission line and alternatives in terms of long-range system development.

## A. Reliability Criteria

### *Definition*

Liberty reviewed the steady state criteria[1] used by Big Rivers to determine if the requirements are reasonable and within the bounds of good utility practice. The review consisted of an evaluation of thermal contingency performance requirements[2] and allowable voltage limits,[3] and an assessment of contingencies chosen for their reasonable likelihood of occurrence. The review also considered whether Big Rivers used appropriate generation bias in its analyses. Generation bias weights the level of generation used in the study compared to how system generation is normally dispatched in a manner to produce conservative results.

[1] Steady state criteria are the outage conditions that a power system is designed to meet for reliability purposes. The criteria state the type of contingencies that must be withstood without overloading equipment while providing adequate voltages to customers.
[2] Part of the steady state criteria that states the types of outages that the system is designed to withstand while maintaining power flow on equipment within its thermal capabilities.
[3] In addition to designing a power system to prevent overloads for reasonably expected contingencies, the system must be designed to provide adequate voltage to customers for proper operation of their electric equipment. Allowable voltage limits on the transmission system are such that if maintained, customer equipment on the lower voltage distribution system will operate properly.

*Discussion*

In 1989, Big Rivers adopted voltage criteria for its 69 kV and 161 kV systems (Table I.1) that specified voltage levels for operation of these systems that would support operation of the low voltage distribution system in compliance with voltage requirements of the Commission and the Rural Utilities Service (*RUS*).[4] Big Rivers adopted criteria for both normal operations and operations under contingency conditions.

When considering the low voltage service requirements, and then reflecting this voltage criteria to high-side buses, Big Rivers considered voltage drop across the transformer, boost supplied by the no-load tap changers, and equipment protection from excessive voltage. It did not consider low-side voltage regulators or load tap changers. For the 69 kV step-down transformers, Big Rivers assumed that they would be set on their middle tap and that the transformer was two-thirds loaded at a 90 percent power factor. For the 161 kV step-down transformers, Big Rivers assumed that they would be set at one tap of boost and would also be two-thirds loaded. The table below summarizes Big Rivers' high-side voltage criteria established to maintain the Commission's required unregulated low voltage criteria.[5]

**Big Rivers High-Side Bus Voltage Criteria**

| Transmission Conditions | 69 kV Bus Voltage - % | | 161 kV Bus Voltage - % | |
|---|---|---|---|---|
| | Minimum | Maximum | Minimum | Maximum |
| Normal | 95.0 | 105.0 | 95.0 | 105.0 |
| Single Contingency | 91.7 | 105.8 | 92.0 | 105.0 |

**Table I.1**

Big Rivers also established design criteria that allows for contingencies on the transmission system. Big Rivers uses N-1[6] criteria applied at peak load levels. Big Rivers defines N-1 as a single line, a single transformer or a generator, and a single line or a single transformer. The Big Rivers criteria are deterministic in nature as they assume that the probability of the outage is 1.00. Under these modeled contingency conditions, system voltages must be within the limits described above and system loadings must be within emergency limits. At Big Rivers, emergency equipment limits are generally the same as normal limits, which are nameplate ratings.[7]

Big Rivers also imposes a reliability criterion on its 69 kV system that it uses as a guideline when loop feeds need to be created for 69 kV radial loads to deal with the exposure of these radial loads to outages. This criterion is known as the 75 MW-mile rule. To apply this criterion, Big Rivers multiplies the radial segments of the 69 kV line in miles by the expected load to be

[4] Low voltage service requirements are the maximum and minimum voltages established by regulating bodies, which must be held by electric utilities, for proper operation of customer equipment.
[5] Big Rivers Transmission Construction Work Plan 2003-2005, Appendix 1.
[6] N-1 refers to the system state as normal minus one element.
[7] Interviews of November 22 and 23, 2004.

served at peak in MW. If the sum exceeds 75 MW-miles, it may create a loop feed to improve reliability.[8]

### *Analysis*

The National Electric Reliability Council *(NERC)* established voluntary reliability standards for utilities to follow. These NERC standards are often referred to as N-1 standards, and require that system voltages and ratings remain within applicable limits under specified conditions. Liberty concluded that Big Rivers' reliability standards are reasonable, since they are consistent with those standards established by NERC.

## B. Thermal Ratings

### *Definition*

Liberty reviewed the thermal ratings of the limiting transmission line components, including equipment in the substation, to ensure that Big Rivers applied appropriate ratings and chose equipment that is reasonably compatible with the system. Liberty reviewed both normal and emergency ratings.

### *Discussion*

Big Rivers generally uses nameplate ratings to rate its equipment and includes thermal limitations on both line-drops and the secondary side of protection and control circuits (5 amps). It rates transformers using their 65 degrees Centigrade rating, if the transformer design had that as its top rating.[9]

Big Rivers has a standard transformer design for application when connecting the 161 kV system to the 69 kV system. It rates those transformers 30/40/50/56 MVA. Both transformers at Meade County substation and one transformer at New Hardinsburg substation are of the standard Big Rivers design. Big Rivers rated the remaining 161/69 kV transformer at New Hardinsburg 30/40/50 MVA; it has no 65 degrees Centigrade rating. It is this smaller transformer that loads the heaviest when in parallel operation because its impedance is less than the transformer of standard design.[10]

Big Rivers rates its lines by a variety of permissible conductor temperatures considering the vintage of line construction and the requirements that existed at the time of construction. It rates older 69 kV lines for 120 degrees Fahrenheit operation. It allows newer 69 kV lines of 336-

[8] Big Rivers Transmission Construction Work Plan 2003-2005, Page 4.
[9] Interviews of November 22 and 23, 2004.
[10] Ibid.

kcmil[11] construction to run at 75 degrees Centigrade and rates them at approximately 67 MVA. Big Rivers constructs 161 kV lines for 100 degrees Centigrade operation. Big Rivers stated that it field-checked all transmission lines to ensure that actual spans maintain National Electrical Safety Code clearances when loaded to allowable temperatures.[12]

### *Analysis*

All electric utilities face the challenge of maintaining different thermal ratings for lines that were constructed under different versions of the National Electrical Code, and incorporating industry advancements for operation of lines at elevated temperatures. Big Rivers' construction design temperature of new 161 kV facilities is comparable with industry high temperature operation. The newer 69 kV lines are limited to 75 degrees Centigrade operation. While this is a lower value, running theses facilities at higher temperatures would produce higher ratings that may not be cost effective. That is, it may be more cost effective to move the power with higher voltage facilities. With this in mind, Liberty concluded that Big Rivers' line ratings are reasonable. Liberty suggests that Big Rivers investigate the development and use of short-term ratings that could be beneficial during switching or other actions under the control of the dispatcher.

The transformer ratings used by Big Rivers are the nameplate ratings guaranteed by the manufacturer. Additional transformer rating capacity can be obtained by taking advantage of the lower 24 hour loading of the transformer[13] existing prior to the contingency of concern. If the design specifications for the transformers at Big Rivers did not include national overload guides, the manufacturer may need to perform a specific evaluation of the transformer. In this respect, Liberty suggests that Big Rivers investigate loading its transformers above manufacturer guaranteed values.

## C. Fault Analysis

### *Discussion*

Utilities perform transient stability studies to ensure that generators remain synchronized to the system during faulted conditions. No generation exists within the Meade County RECC service territory.[14] Big Rivers performed no transient fault analyses as part of its justification or investigation into the need for the proposed New Hardinsburg to Meade County 161 kV transmission line.

[11] Thousands of circular mils in area.
[12] Interviews of November 22 and 23, 2004.
[13] This "thermal lag effect" allows a utility to increase the short-term overload capability of a transformer based upon its prior "heating up" during the prior 24 hour loading.
[14] Interviews of November 22 and 23 2004.

***Analysis***

Liberty concurs that a transient stability analysis[15] is not required in support of the application for the proposed 161 kV transmission line as there is no generation within the Meade County RECC service territory and very little generation near enough to Meade County RECC that could be impacted by faulted conditions.

## D. Load Forecasting

***Definition***

Liberty reviewed Big Rivers' load forecasting methods on both a system and sub-system basis to assess whether it represented the future in a reasonable manner. Items reviewed included the use of weather-based forecasting and the weather inputs to the forecast. Liberty also reviewed the econometric model assumptions used in load forecasting.

***Discussion***

The summer load for Big Rivers in 2004 was approximately 1,450 MW. The load of Big Rivers' three distribution cooperatives is approximately as follows:

| | |
|---|---|
| • Jackson Purchase Energy Cooperation | 143 MW |
| • Kenergy Corporation | 245 MW |
| • Meade County CC load | 83 MW |
| **Total Distribution Load** | **471 MW** |

The remainder of the Big Rivers' load is associated with a few large industrial customers, none of which are on the Meade County RECC system.[16] As noted earlier, the proposed line would serve as a second 161 kV power supply to the Meade County substation and would backup the existing line that currently serves this substation.

Big Rivers performs its load forecast every two years in conjunction with the three distribution cooperatives. Each distribution cooperative develops a forecast for its own coincident peak load at the low side of the 69 kV step-down transformers. The distribution cooperatives own the step-down transformers. Big Rivers then adjusts these three coincident peak loads, along with the smaller coincident peak load experienced by the Big Rivers system (as explained below), and models the combined load on the high side of the step-down transformers to develop the overall load forecast. Big Rivers has recognized that there are losses in going from the low side of the

[15] Transient stability analysis is the time response mathematical power flow analysis that is performed to ensure that the power system is designed and operated in such a manner that angular difference between generators on the power system does not become so great that generation and/or load is disconnected from the system.
[16] Interviews of November 22 and 23, 2004.

step-down transformers to the high side of these transformers, and has plans to correct this modeling problem in its 2005 analyses by adding the transformers to the model or adjusting for the losses in these transformers.[17]

In order to provide historical perspective, actual loads experienced by Meade County RECC have been as follows:

**Actual Meade County RECC Loads**

| Summer - Year | Load – MW | Winter – Year | Load – MW |
|---|---|---|---|
| 2000 | 84 | 2000/2001 | 88 |
| 2001 | 82 | 2001/2002 | 84 |
| 2002 | 87 | 2002/2003 | 101 |
| 2003 | 85 | 2003/2004 | 102 |
| 2004 | 83 | | |

**Table I.2**

In July 2002, when Big Rivers conducted the overall system analysis on which it based the application for the new 161 kV transmission line, it used the latest available load forecast, which was the one conducted in 2001 that developed forecasts for the 2003 – 2005 Transmission Work Plan. At that time, the projected summer peak load for 2005 for Meade County RECC was 98 MW.[18]

Big Rivers performs its load forecasting by evaluating the sensitivity of the forecast to variations in weather and to economic conditions. The base case forecast, and the forecast used in the Big Rivers analysis for the proposed 161 kV transmission line, used average weather and the base case economic forecast. The weather sensitivities evaluated were the most mild and the most extreme conditions experienced in the last twenty years for both the summer and winter seasons. Sensitivities of the forecast to economic conditions included both an optimistic and pessimistic case. Although it did not do so in support of the application for the new 161 kV transmission line, in developing its high load forecast, Big Rivers uses the highest loads produced by either the extreme weather/normal economy or the optimistic economy/average weather cases. Big Rivers uses similar but opposite combinations to produce the low load forecast.[19]

Big Rivers uses the Data Resources International (*DRI*) regional forecast as its initial econometric forecast and subsequently adjusts it with available local county economic data and data available from the University of Louisville. The analysis conducted is referred to as a "bottoms-up" analysis because of the manner in which Big Rivers builds the forecast from fundamental information. In those counties where only a portion of the county is served by Big

[17] Ibid.
[18] Ibid.
[19] Ibid.

Rivers distribution cooperatives, Big Rivers attempts to adjust the data to fit the actual service territory. After Big Rivers develops an economic forecast for each distribution cooperative that corresponds to its coincident peak load, Big Rivers then meets with each company to confirm the validity of the adjustments made by Big Rivers, as well as the validity of the forecast. Big Rivers forecasts demand separately from energy and does not apply load factors to monthly energy to obtain peak demands. Big Rivers stated that its reasoning for separate demand forecasting was that it can experience low energy/high demand and high energy/low demand summer peaks because of weather.[20] Big Rivers' approximate 50 percent system load factor, compared to many systems that have 60 percent or better load factor, supports that reasoning.

Big Rivers' most recent load forecast available in July 2002, at the time it conducted the study justifying the need for the new transmission line, was the 2001 forecast. Big Rivers stated that the 2003 forecast process was essentially the same as the one used in 2001, and that it produced similar results to those obtained through the 2001 forecasting process. Big Rivers is in the process of performing its 2005 load forecast. The 2005 process is again similar to that used in previous years, and Big Rivers has not seen updated information that alters its view of future forecasted load for Meade County RECC.[21] The table below shows the results of the forecasts supporting these statements.

**2001 and 2003 Forecasts of Summer Meade County RECC Loads**

| 2001 Load Forecast[22] | | | | 2003 Load Forecast[23] | | |
|---|---|---|---|---|---|---|
| Year | Base – MW | Extreme - MW | | Year | Base - MW | Extreme - MW |
| 2003 | 93 | 94 | | 2003 | 92 | 98 |
| 2005 | 98 | 100 | | 2005 | 97 | 104 |
| 2007 | 104 | 107 | | 2007 | 103 | 110 |

**Table I.3**

Big Rivers stated that the winter peak load for its entire system is about the same as its summer peak load or a little higher. Big Rivers generally uses summer loading conditions as the basis for its load forecasting because system component ratings are lower in the summer and the reactive load[24] associated with the summer load is higher. These higher reactive loads produce voltage

[20] Ibid.
[21] Ibid.
[22] Pages B-2 and C-2, 2001 Meade County CC Load Forecast.
[23] Pages B-2 and C-2, 2003 Meade County CC Load Forecast.
[24] Voltage and current alternate their magnitude 60 times a second in accordance to their sinusoidal waveform. When the angular difference between the two is zero, all power flowing is called "real power" and can be measured in Watts. When the voltage waveform is angularly ahead of the current waveform, power other than Watts is required to satisfy the power relationship. This power is called "reactive or imaginary" power. In this case, it is inductive reactive power that is required and this reactive power (lagging) tends to lower system voltage. Similarly, when the current waveform angularly leads the voltage waveform, capacitive reactive power (leading) is required to satisfy the power relationship and system voltage is raised. Reactive power is also referred to as VARs, or Volt Amperes Reactive.

limits on the system. Big Rivers has little control over the power factor maintained by the three distribution cooperatives as the contracts between Big Rivers and its three distribution cooperatives are in place until approximately 2023 and require that the distribution cooperatives only maintain a 90 percent power factor (generally measured at the low side of the step-down transformers). Big Rivers also stated that it would begin analyzing winter conditions in the future and would factor those analyses into its load forecasts.[25]

### *Analysis*

Discounting the four major industrial loads served by Big Rivers, the 475 MW distribution load places Big Rivers into the category of a relatively small utility. Liberty found that the Big Rivers load forecasting process used techniques, examined customer detail, and investigated sensitivities in a manner usually found with much larger utilities. Liberty concluded that the load forecast process is reasonable.

Big Rivers uses its "base case" load forecast when performing its planning studies. This load forecast represents average weather conditions and base economic projections. In some areas of the United States, the use of average weather forecasts (those that have a 50 percent probability of being exceeded in any year) in reliability analysis for summer conditions has not proved to be conservative. While Big Rivers had data available to it on projected higher loads using more extreme weather conditions for its application for the new 161 kV transmission line, these data were not used in support of the application. Liberty believes that use of load forecasts that are based on more extreme weather conditions is required.

## E. Technical Analysis

### *Definition*

Liberty reviewed the power flow[26] and other technical analyses used to justify the project. Other technical analyses could include reactive requirements or short circuit analysis. The review consisted of a review of the size of the system model used for the analysis to determine if it is of sufficient size and of sufficient detail to produce valid study results, the application of the reliability criteria to assure proper simulations, and a review of the results themselves to ascertain whether Big Rivers drew proper conclusions from its analysis.

[25] Interviews of November 22 and 23, 2004.

[26] Power flow analysis is done with a mathematical impendence model of the power system. Final or steady state (when angular change between generators has ceased) voltages are calculated at nodes and power flows are calculated on the various pieces of equipment. Contingencies are simulated to ensure that equipment loadings and voltages stay within prescribed limits.

***Discussion***

Liberty reviewed the power flow model used by Big Rivers to conduct its analysis to ensure that the model was a reasonable representation of the system and of sufficient detail to produce valid study results. Big Rivers developed its model on the basis of the ECAR base case developed by its model maintenance working group. In addition to a detailed model of its own system, Big Rivers included surrounding systems, Hoosier Energy and LG&E, in reasonable detail. Big Rivers included the 69 kV system and higher voltage systems in its model, but did not include 69 kV step-down transformers. There is no local generation on the Meade County RECC system to model. Big Rivers used a constant MW and a constant MVAR load model in its simulations. Big Rivers used the General Electric, PSLF power flow software package to conduct the analysis. This software package is nationally recognized as industry state of the art.[27]

The Meade County RECC system is a three-loop, 69 kV system that is fed from two 161/69 kV Big Rivers' substations and operated with all three loops open.[28] The major 69 kV arteries were constructed prior to the formation of Big Rivers or within five years of its formation. Oil circuit breakers exist only at the New Hardinsburg and Meade County substations. The loops are only closed to remedy contingency conditions. Big Rivers indicated that the three system loops were originally opened primarily to reduce system losses and secondarily to reduce exposure to outages. The open points are Union Star to Andyville, Custer to Flaherty, Garrett to Doe Valley Tap, and Battletown to Brandenburg. Big Rivers also indicated that it has SCADA control of all open points except Custer to Flaherty.[29]

Big Rivers indicated that if the existing 161 kV transmission line from New Hardinsburg to Meade County is lost at peak load, then even after available switching, the New Hardinsburg to Irvington 69 kV line will be overloaded (sag limited), the smaller 161/69 kV transformer at New Hardinsburg will be overloaded, and 69 kV voltages will be below those required by their voltage criteria.[30] Big Rivers also indicated that because of the impacts of that contingency, maintenance on the New Hardinsburg to Meade County 161 kV line could not be performed at load levels above 80 MW.[31]

Big Rivers performed a short circuit analysis[32] of its system to ensure that circuit breaker interrupting capabilities were within rated values. Big Rivers represented its system in detail and modeled all generators and ground sources. Big Rivers represented the systems of others with a

[27] Interviews of November 22 and 23, 2004.
[28] An "open loop" is a loop of a transmission line that is normally operated with a switch in that loop in an open position to prohibit circular power flow in that loop. The switch may be closed for a variety of operational circumstances.
[29] Ibid.
[30] October 25, 2004 application of Big Rivers, page 6.
[31] Ibid, page 7.
[32] When faults occur on the power system, "short circuits" are created and current flows. To isolate the faulted element, power system protective devices must interrupt the current that is flowing into the fault. The power system is mathematically modeled so that the amount of current flowing into the fault is calculated. Power system protection equipment can only interrupt finite current values. Interruption of fault currents above rated value can cause equipment damage.

mathematical equivalent. Big Rivers simulated three-phase and single-phase faults at each circuit breaker to ensure that it captured the worst conditions. Big Rivers uses the nameplate interrupting rating of its breakers as the replacement value.[33]

Big Rivers also studied step and touch potentials at the Meade County substation to ensure that the higher short circuit currents available because of the construction of the second 161 kV feed would not create safety concerns. Big Rivers indicated that it supplies new source impedances[34] to the distribution cooperatives when system changes are made. In this manner, the distribution cooperatives may make required fault analysis evaluations of their own systems.[35]

Big Rivers performed a 30-year levelized economic evaluation of the proposed 161 kV transmission line alternative assumed to be in service by the summer of 2004, the 69 kV tie to Hoosier Energy assumed to be in service in 2004, and the replacement of the New Hardinsburg smaller transformer also assumed to be in service in the summer of 2004. The 69 kV tie to Hoosier Energy delayed the proposed 161 kV line for 2 years and the transformer replacement at New Hardinsburg delayed the proposed 161 kV line for 4 years. It also included additional system requirements to year 2010 in the analysis. Big Rivers used a 4 percent inflation factor, depreciation of 2.75 percent per year, property taxes and insurance at 0.5 percent per year, 6.0 percent cost of money, and a levelized fixed charge rate of 7.3 percent. The total 2002 present value of the preferred alternative was $5.1 million, the New Hardinsburg transformer replacement was $6.0 million, and the 69 kV tie to Hoosier Energy was $7.4 million.[36]

Big Rivers indicated that it assumed that Operations and Maintenance (O&M) expenses would be zero. Big Rivers also indicated that it was not required to pay federal income tax, but was required to pay the alternative minimum tax if it applied for a particular year. However, the alternative minimum tax was not included in the analysis.[37]

### *Analysis*

In evaluating the technical analyses conducted by Big Rivers, Liberty reviewed the Big Rivers Transmission Construction Work Plan 2003-2005 conducted in July of 2002. In Appendix 3, case MC-15 represents the 2005 system with the outage of the existing New Hardinsburg to Meade County 161 kV line. This case shows the 266.8 kcmil New Hardinsburg to Irvington line loaded to 62 MVA (far exceeding its rating), the smaller Hardinsburg transformer loaded to 56 MVA (rated 50 MVA), and four 69 kV buses below established voltage criteria. Cases MC-16 and MC-17 demonstrate that even with switching, the smaller transformer at New Hardinsburg remains overloaded at 55 MVA and that high and low voltage violations can exist simultaneously.[38] Liberty found the system representation constructed by Big Rivers to be

[33] Interviews of November 22 and 23, 2004.
[34] Another term for system equivalent.
[35] Interviews of November 22 and 23, 2004.
[36] Big Rivers Transmission Construction Work Plan 2003-2005, appendix 2.
[37] Interviews of November 22 and 23, 2004.
[38] Big Rivers Transmission Construction Work Plan 2003-2005, appendix 3.

reasonable, the application of its reliability criteria to be proper, and that Big Rivers drew the proper conclusions from its analysis.

With respect to the issue of power factor improvement, Liberty believes that the sizing and placement of the large capacitor bank at Meade County creates both high and low voltage violations at the same time. Using smaller capacitors and installing them at various places in the system with SCADA control would have obtained a more appropriate voltage profile. However, even if Big Rivers did that, the loading on the smaller transformer at New Hardinsburg would not be affected.

Also with respect to power factor issues, Liberty draws attention to the 2005 base case, MC-1. In that case, 96 MW of load is being served and 53 MVAR of reactive power is being drawn from the Meade County capacitor bank or the 161 kV system. The system is running below a .90 power factor at peak summer load and Liberty expects this condition to deteriorate with the increased loads expected through time. Of the 53 MVAR reactive load on the system, 14 MVAR is reactive losses and 39 MVAR is associated with the 95 MW of distribution load. The distribution load is at .91 power factor not including the losses in the transformers. It appears that Meade County RECC is barely complying with its .90 power factor contractual requirement and that this is most likely a financial decision on its part. Liberty believes that installation of reactive supply on the Meade County RECC system would not only help to solve voltage problems on both the Big Rivers and Meade County RECC systems, but would also reduce losses and therefore costs to both.

Because there is no generation on the Meade County RECC system, generation bias in the studies was not an issue in this review.

When new system components are added to the system, source impedances are decreased and fault currents are therefore increased. Increased fault currents require equipment with higher fault duty capability and can increase the potential of shock to station personnel. Liberty's review of the fault analyses performed by Big Rivers found them to be adequate.

Liberty believes that the economic analysis has weaknesses. O&M should have been included as it could be different for the varied alternatives on an annual basis. The Federal alternative minimum tax should also be included as the annual responsibility to potentially pay the tax may be different with each alternative. The system expansion horizon should also match the length of the economic analysis. Finally, Big Rivers should use the actual annual costs rather than average annual costs when performing economic analysis of deferrals. With the foregoing said, Liberty believes that the weaknesses cited do not rise to a level that would alter the economic results or the selection of the preferred alternative, especially when the reduced reliability of the alternatives to the proposed project is considered. Three facts support Liberty's reasoning for this conclusion: Big Rivers pays no federal income tax, which reduces the sharp up front carrying costs required by investor-owned utilities due to accelerated depreciation; Big Rivers rarely pays the alternative minimum tax; and O&M on new facilities is generally quite low.

# F. Summary

In this chapter, Liberty concluded the following related to each of the subsections of the chapter:

***Reliability Criteria***

The reliability criteria established by Big Rivers are reasonable and consistent with national standards established by NERC.

***Thermal Ratings***

The thermal ratings used by Big Rivers for its lines are reasonable, but could benefit through development and use of higher short-term ratings that could defer future investment and that could be beneficial during switching or other actions under the control of the dispatcher.

Additional transformer rating capacity might be obtained by taking advantage of overload capabilities developed in conjunction with the transformer manufacturers.

***Fault Analysis***

Liberty concurs with Big Rivers that a transient stability analysis is not required in support of the application for the proposed 161 kV transmission line.

***Load Forecasting***

The overall load forecasting process used by Big Rivers was reasonable. Big Rivers could benefit in the future from incorporation of more extreme weather conditions into its load forecasts for system design.

***Technical Analysis.***

The overall technical analysis conducted by Big Rivers included a reasonable representation of the system, proper application of reliability criteria, and proper conclusions were drawn. Big Rivers' studies and analyses used industry-accepted software and were of sufficient quality, completeness, and detail to produce reasonable results.

# II. Alternatives

### *Scope*

This chapter addresses the following topics:

- Upgrades
- Addition of generation and power factor improvement
- Wheeling.

### *Background*

This chapter presents the results of Liberty's evaluation of the analyses that support Big Rivers' need for the proposed transmission line. The evaluation included whether Big Rivers gave adequate consideration to:

a. The upgrade of existing lines or facilities and transmission routes,
b. Other alternatives, including the use of generation and power factor improvement, and
c. Whether wheeling power through neighboring systems to the north or east of Meade County RECC or through interconnections with LG&E would be a viable alternative to construction of the proposed new transmission line.

## A. Upgrades

### *Definition*

Liberty evaluated whether Big Rivers gave adequate consideration to upgrades of existing transmission lines for both Big Rivers and neighboring utilities and use of alternative transmission line routes. Liberty included a review of the cost analysis of the alternatives presented by Big Rivers and a review of the application of new technology or automation to the solution.

### *Discussion*

When a utility develops concerns related to the operation and reliability of its system, it can explore a number of alternatives for improvement of the system. One such alternative is to upgrade the existing system. The 161 kV line from New Hardinsburg to Meade County proposed by Big Rivers is such an upgrade. In addition to the alternatives that Liberty discusses elsewhere in this report, Liberty identified two other alternatives that Big Rivers should have considered for upgrading its system. One alternative would be to construct a 161 kV line from New Hardinsburg to Custer along the LG&E Hardin to New Hardinsburg 138 kV right-of-way and

build a 161/69 kV substation at Custer.[1] The other alternative is to build the proposed New Hardinsburg to Meade County 161 kV line along the route of the existing 161 kV New Hardinsburg to Meade County line or beside the existing New Hardinsburg to Meade County 69 kV line.

Big Rivers considered the replacement of the smaller New Hardinsburg transformer as an option to provide for the loss of the New Hardinsburg to Meade County 161 kV line contingency. In addition to that replacement, 3 miles of the New Hardinsburg to Irvington 69 kV line must be re-sagged and rebuilt over a 10 mile section to alleviate the thermal loadings on that facility. Big Rivers indicated that this alternative is more costly and less robust than the preferred alternative. Voltages could be maintained by reconfiguration of the system.[2] This alternative would delay the need to reinforce the Meade County substation by 4 years.[3]

### *Analysis*

Although a 161 kV line from New Hardinsburg to Custer would be a few miles shorter than the proposed line, the new Custer substation would be an additional cost to the project of approximately $2,000,000. Another disadvantage to this alternative is that while supplying required system relief, it would not be as reliable as the proposed project. Under this possible alternative, the Meade County substation would not have the advantage of the looped 161 kV feed as it does in the proposed alternative.[4]

Both of the alternatives for the proposed facilities that follow existing transmission routes would cost approximately the same because the equipment required at Meade County and the lengths of the routes are similar. Following existing routes has the disadvantage that single contingency events can interrupt two transmission paths to Meade County. Those alternatives are therefore not as robust as the preferred alternative. In addition, following the 69 kV transmission line route from New Hardinsburg to Meade County would require the construction of the new 161 kV line through the City of New Hardinsburg. Liberty concurs with Big Rivers that the proposed alternative is more robust.

Liberty concurs with Big Rivers that the preferred alternative of constructing a new 161 kV line from New Hardinsburg to Meade County is a more robust solution for supplying reliable power to Meade County RECC. The existing New Hardinsburg substation is fed from two 161 kV lines from Skillman and Paradise. Although this loop is normally operated with a switch opened at some point (preventing loop flow) as part of the proposed project, it is reestablished with the construction of the proposed line and the existing New Hardinsburg to Meade County 161 kV lines. In this manner, both 161 kV supply points to Meade County RECC are fed via looped feeds. Replacing the smaller New Hardinsburg transformer leaves Meade County on a radial feed

[1] Interviews of November 22 and 23, 2004.
[2] Big Rivers memo, Summary of Need for the New Hardinsburg to Meade County 161 kV Circuit, dated 11/12/04.
[3] Big Rivers Transmission Construction Work Plan 2003-2005, appendix 2.
[4] Interviews of November 22 and 23, 2004.

and is more costly. Liberty believes that as Big Rivers advances its capabilities to defer system investment, the preferred alternative provides a much better platform to build upon.

Liberty identified no other system upgrades that could provide the required system relief.

## B. Addition of Generation and Power Factor Improvement

### *Definition*

Liberty evaluated whether Big Rivers gave adequate consideration to the installation of generation within the Meade County RECC service territory and whether power factor improvement was a viable alternative.

### *Discussion*

In addition to on-system upgrades or interconnections with neighboring systems, there are other alternatives that may solve reliability problems. In cases where a utility encounters thermal restrictions, it can consider the addition of local generation. When a utility experiences voltage constraints, it may employ the addition of capacitors (or other reactive devices).

Big Rivers considered the addition of local generation to the Meade County RECC system. It calculated that 15 MW to 20 MW of local generation would be required to reduce the load on the smaller transformer at New Hardinsburg and the New Hardinsburg to Irvington 69 kV line. Big Rivers also indicated that industry restructuring legislation did not prevent it from owning local generation to resolve local reliability issues. No natural gas fuel source exists in or near the Meade County RECC system. Because there was no fuel source to support local generation of this magnitude, Big Rivers eliminated this option from additional consideration.[5]

Big Rivers has recently installed a 27.5 MVAR (nominal) capacitor bank on the Meade County 69 kV substation bus at a cost of $272,000. Big Rivers indicated that it installed this capacitor at the Meade County substation because Meade County RECC owns all of the 69 kV step-down substations and none of them have SCADA.[6,7] SCADA allows system operators to remotely operate equipment such as breakers, switches, and capacitors. Big Rivers also indicated that it will not size capacitor banks larger that the value needed to obtain a unity power factor at that load bus at peak load conditions.[8]

[5] Ibid.
[6] Supervisory Control and Data Acquisition.
[7] Interviews of November 22 and 23, 2004.
[8] Big Rivers Transmission System Construction Work Plan 2003-2005, page 5.

*Analysis*

Liberty concurs with the Big Rivers decision to eliminate installation of local generation as an alternative. In addition to the installation cost of the generation, additional significant investment would be required to bring adequate fuel sources to the Meade County RECC service territory and would most likely involve additional time for permitting. The generation would have to be located inside the Meade County RECC service territory to alleviate the overloads on the New Hardinsburg transformer and the New Hardinsburg to Irvington 69 kV line.

In the Big Rivers analysis, the "base case" plot, referred to as MC-1, shows that at peak load, the transformers at Meade County substation are slightly above unity power factor and that the Meade County RECC system as a whole is at approximately .99 power factor.[9] Thus, little room is left to accommodate additional capacitors, or other reactive devices based on new technology, for reactive support. A utility normally does not want to operate its system above unity power factor (1.00). Therefore a very limited amount of capacitors may be added for voltage improvement and MVA reduction when the existing power factor is .99. Liberty also notes that plot MC-17 shows that during contingency conditions, and under certain switching scenarios, both high and low voltage violations occur at the same time.[10] This result is due to a capacitor planning and sizing problem. In any event, just solving the voltage problems will not alleviate the overloads on the smaller New Hardinsburg transformer or the New Hardinsburg to Irvington 69 kV line.

## C. Wheeling

*Definition*

Liberty reviewed whether Big Rivers gave adequate consideration to wheeling power from/through adjoining systems via existing or new interconnections with LG&E or other systems to the north and east of Meade County RECC. Liberty included a review of the cost analysis of the alternatives presented by Big Rivers and a review of the application of new technology or automation to the solution.

*Discussion*

The service territory of Meade County RECC is on the northern edge of Kentucky and borders the Ohio River. Big Rivers investigated a 5-mile interconnection between the Hoosier Energy 69 kV Mauckport substation and the 69 kV Meade County RECC Battletown substation as part of its evaluations associated with improving system reliability. Mauckport, Indiana is located in a very rural part of Indiana and is distant from strong electrical sources.[11] In Big Rivers' analyses,

[9] Ibid, Appendix 3.
[10] Ibid.
[11] Interviews of November 22 and 23, 2004.

power flow simulations revealed that this 5-mile interconnection would only supply a limited amount of relief (10 MW). The analyses also indicated that additional system investment would be required in two years if it pursued this alternative. This 5-mile interconnection also required an expensive crossing of the Ohio River[12]. For these reasons, Big Rivers eliminated the 5-mile interconnection as a possibility.

The transmission system of LG&E also traverses Big Rivers' transmission lines that supply Meade County RECC.[13] One LG&E transmission line investigated by Big Rivers for a possible interconnection was the Mill Creek to Cloverport 138 kV line at Irvington Kentucky. Big Rivers had been discussing this possible 161/138 kV interconnection with LG&E since 1999 and had determined that approximately 40 MW of relief could be obtained for the Meade County RECC system if it established such an interconnection. It would need to construct an approximate 3-mile 161 kV line from the new Irvington substation to the Meade County substation.

Late in 2001, LG&E indicated that it would need to reconductor approximately 28 miles of 138 kV transmission line from Mill Creek to the proposed Irvington substation[14] at $200,000 per mile. LG&E indicated that even with such construction completed, voltage constraints may still exist on the LG&E system that would require more expenditures. LG&E also indicated that its own analyses confirmed this limitation.

Another factor Big Rivers considered was that wheeling power through the LG&E system would accrue wheeling charges levied by the Midwest Independent System Operator. This alternative was Big Rivers' original preferred solution for the Meade County RECC reliability problem as it supplied a diversified feed to Meade County RECC. Big Rivers abandoned this alternative as too expensive and unlikely to proceed to construction prior to the conduct of its 2003-2005 Transmission Construction Work Plan. During the interviews conducted by Liberty, and as a result of issues raised by Liberty, Big Rivers asked LG&E if operating with this interconnection closed and then opening it when required by LG&E would change the upgrade requirements. LG&E indicated that it would not.[15]

Big Rivers indicated that it had considered a 69 kV interconnection with LG&E at the Big Rivers 69 kV Brandenburg substation. Such an interconnection would have been where the LG&E 69 kV system that feeds LG&E's Brandenburg substation is also fed from the Mill Creek to Cloverport 138 kV line. Because such an interconnection would require the same upgrades as the 161/138 kV interconnection discussed above, Big Rivers abandoned it as well.[16]

The LG&E Hardin to New Hardinsburg 138 kV transmission line crosses the Big Rivers McDaniels to Custer 69 kV line near the Custer substation. During the interviews conducted by Liberty, and as a result of issues raised by Liberty, Big Rivers asked LG&E if a 138/69 kV interconnection at this location would be feasible. LG&E responded that a tap at this location

[12] Big Rivers Transmission Construction Work Plan 2003-2005, Appendices 2 and 3.
[13] KPSC transmission map for Case No. 2004-00365, dated November 4, 2004.
[14] Normal power flow is from Mill Creek to Cloverport.
[15] Interviews of November 22 and 23, 2004.
[16] Ibid.

would accelerate replacement of the Hardin 345/138 kV autotransformer, which was already heavily loaded.[17] In addition, a new Custer 161/69kV substation would be required at a cost of approximately $2,000,000.

Big Rivers indicated that they had briefly considered a 161/138 kV interconnection with LG&E at New Hardinsburg. In addition to the proposed line costs, the construction of an additional 161/138 kV substation would be required, and wheeling charges would also apply. Accordingly, Big Rivers rejected this alternative.[18]

As part of this case, Big Rivers submitted responses to the Commission Staff's First Data Request of December 3, 2004. Liberty has reviewed these responses from Big Rivers and finds that they coincide with and support the conclusions that Liberty has drawn from its own investigations in this project.

### *Analysis*

The potential tie to Hoosier Energy is of limited value, provides relief of reliability problems for only a two-year period, and requires an expensive crossing of the Ohio River. Due to the remoteness of the service territory on the Indiana side of the Ohio River, Liberty concluded that this alternative had little or no long-term benefits.

Although Liberty did not participate in discussions regarding possible interconnections with LG&E, it appeared evident to Liberty that such discussions were a courtesy to Big Rivers. While Liberty has not discussed any issues with LG&E, it appears that LG&E is not interested in establishing any interconnections with Big Rivers. The problems cited by LG&E should have been evident to LG&E early in the process. Liberty concluded that wheeling power through the LG&E system, although desirable from a system development point of view, was not a viable option to the proposed construction. In each case, the cost of interconnection and associated upgrades exceeded the cost for construction of the proposed new 161 kV transmission line.

## Summary

Liberty has developed two major conclusions related to the need for the 161 kV transmission line proposed by Big Rivers:

1. Big Rivers needs the construction of its proposed New Hardinsburg to Meade County 161 kV transmission line to meet the electric service requirements of Meade County RECC.

[17] Ibid.
[18] Ibid.

2. Big Rivers performed the appropriate system studies and analyses to justify the need for the proposed 161 kV transmission line. Big Rivers appropriately considered least cost alternatives, including reasonable on-system upgrades, interconnections with and wheeling through neighboring electric systems, installation of on system generation, and the use of power factor correction.

In this chapter, Liberty concluded the following related to each of the three subsections of the chapter:

***Upgrades***

Liberty concurs with Big Rivers that the preferred alternative of constructing a new 161 kV line from New Hardinsburg to Meade County is a more robust alternative for supplying reliable power to Meade County RECC. Liberty has not identified other upgrades of the existing system that appear capable of providing the required system relief at lower cost.

***Addition of Generation or Power Factor Improvement***

Liberty concurs with the Big Rivers decision to eliminate installation of local generation as an alternative. Also, there are no opportunities for significant power factor improvement that could provide the required system relief. Big Rivers could benefit from power factor correction coordinated with its distribution cooperatives.

***Wheeling***

Liberty concurs with Big Rivers that there are no opportunities for wheeling power through neighboring utility systems via existing or new interconnections, including LG&E's system, that could provide the required system relief.