#R97 Rockport 765kV

Generation Interconnection

This analysis was completed to assess the reliability impact for the increase in generation interconnecting to the PJM system as a capacity resource.

Network Impacts

The #R97 project was studied as a capacity injection of 20 MW into the Rockport 765 substation. Project #R97 was evaluated for compliance with reliability criteria for summer peak conditions. Potential network impacts were as follows:

Generator Deliverability

(Single or N-1 contingencies for the Capacity portion only of the interconnection)

No problems identified

Multiple Facility Contingency

(Double Circuit Tower Line, Line with Failed Breaker and Bus Fault contingencies for the full energy output)

No problems identified

Short Circuit

No problems identified

Stability Analysis

Stability studies were not performed as part of this Feasibility Study and are not typically performed as part of the Feasibility Study effort. The stability assessments are part of the System Impact Study. Therefore, based upon the results of the future System Impact Study assessment, which includes the stability assessment, the extent of system upgrades could be significantly different from those identified in this Feasibility Study.

Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

No problems identified

New System Reinforcements

(Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, initially caused by the addition of this project generation)

None

Contribution to Previously Identified System Reinforcements

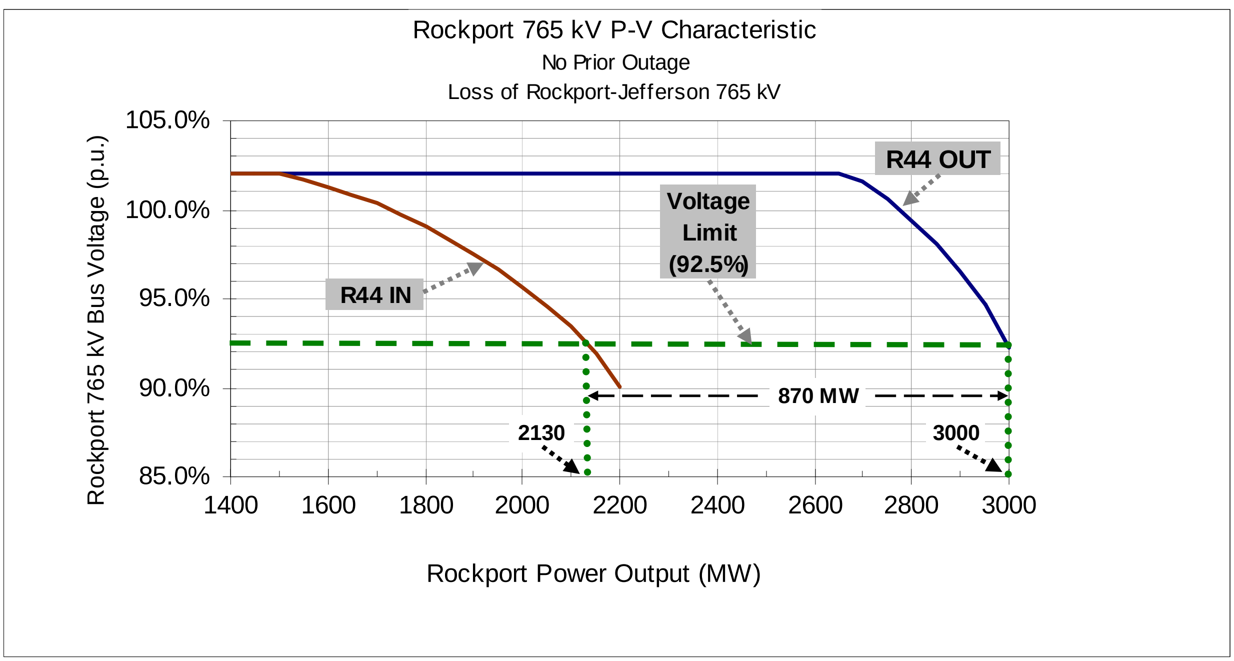
(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)

None

Discussion of AEP Analysis of Connection at Rockport 765kV Substation

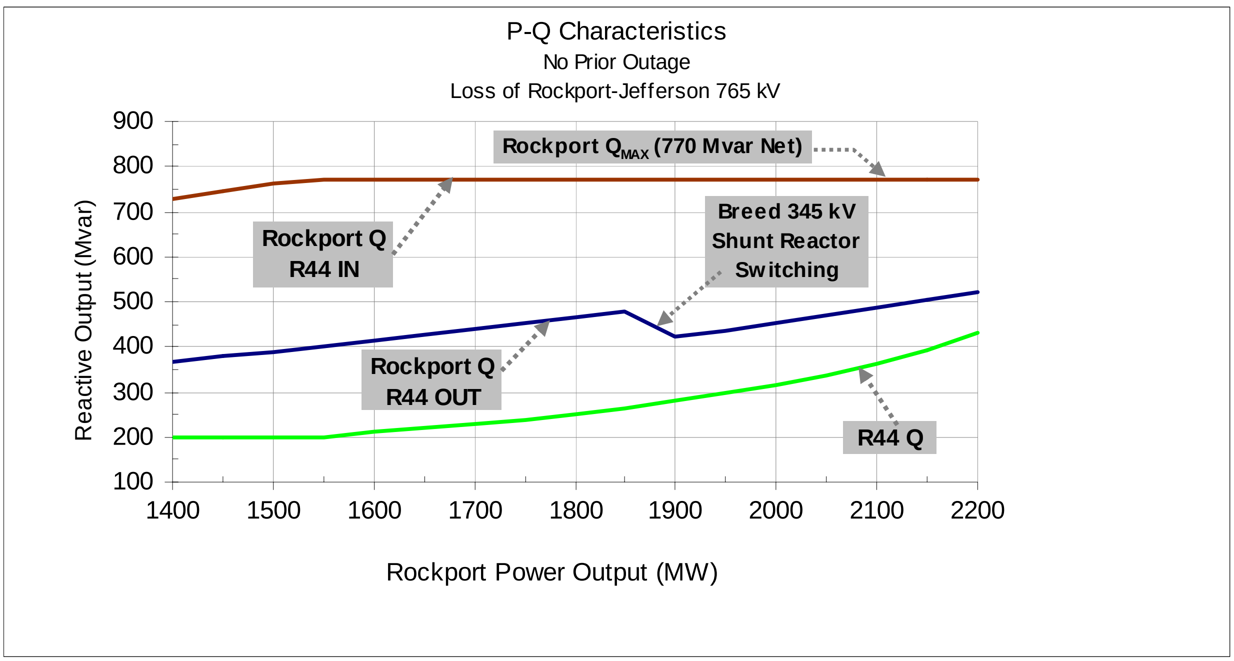
The discussion below was developed for the R44 640MW project that has been proposed for interconnection to Rockport substation. Much of the discussion is pertinent to the R97 project since it adds an additional 20 MW to the Rockport substation.

> Study results indicate that connecting IPP R44 generation to AEP at the proposed level of 745 MW would prevent the Rockport Plant from operating at its net demonstrated capability (2600 MW). This conclusion is based on Power vs. Voltage (P-V) analysis of the Rockport Plant and vicinity under 2011 summer peak load conditions, before and after R44 is modeled in service. The results of the P-V analysis are presented below. These are curves of the Rockport 765 kV bus voltage as a function of the plant output. The minimum allowable 765 kV bus voltage for Rockport is 92.5%, based on requirements of the auxiliary motor load of the plant. The point at which the Rockport 765 kV bus voltage drops to 92.5% is the maximum allowable power output of the plant before any margin is applied. A margin of 100 MW is presently applied to (subtracted from) the power output at the minimum 765 kV bus voltage to protect against uncontrollable system conditions that may evolve but are not simulated in the P-V analysis, due to their randomness and unpredictability.



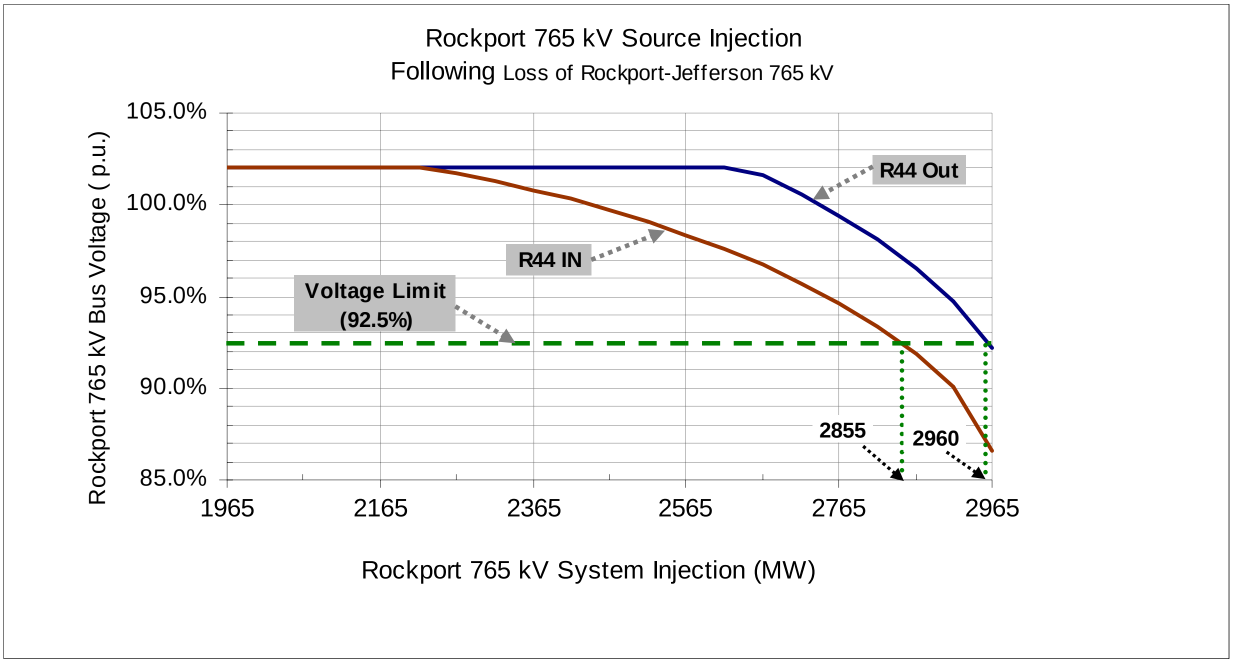
The curves in this exhibit indicate that the maximum permissible output of the Rockport Plant will drop by 870 MW if R44 is placed in service at its stated output of 745 MW. The curves show that before R44 is added (blue line) and with Rockport Plant output at 3000 MW, the 765 kV bus voltage will drop to 92.5% should Rockport-Jefferson 765 kV be opened (worst contingency) while all other facilities are in service. A comparable voltage drop will occur with Rockport plant output at 2130 MW after R44 is added. These are the levels before the 100 MW margin (present recommendation) is applied. With the margin applied, the Rockport Plant output limits would be 2900 MW and 2050 MW (limits are generally rounded to nearest 50 MW), respectively.

The next set of curves presents a possible explanation for the results shown in the first set. The curves in this exhibit present the reactive power outputs of Rockport and R44 following the worst contingency (Rockport-Jefferson 765 kV).



These curves indicate that the Rockport Plant reactive power output capability will be depleted sooner with R44 in service (red line), even if R44 also contributes reactive power to the network (green line). Without R44 (blue line), the reactive output of Rockport increases as generation output increases, but not as rapidly as with R44 in service. Note that the Breed 345 kV shunt reactor (250 MVAR) was automatically switched out in the simulations run for this analysis, and the power output limits in the first chart reflect this action.

The last set of curves presents the maximum Rockport 765 kV bus power injection into the network without R44 in service and with R44 generating at its stated level of 745 MW.



These curves indicate that the Rockport 765 kV bus can presently inject over 2900 MW into the network and not fall below its minimum voltage limit. The maximum power injection at Rockport is reduced with R44 in service, due to the additional transmission line losses on the 345 kV line from Rockport to R44. However, these losses can be reduced by installing a second line to R44 or reducing R44 power output or both. The R44 output used in this study is based on the value quoted in the project's request for connection (Attachment N), but other data submitted by R44 indicates that 745 MW is the gross output and that the plant auxiliary load is 149 MW. Assuming that the maximum injection is about 2950 MW if a smaller plant is placed in service, and considering the 100 MW margin observed at Rockport and the present Rockport Plant net capability of 2600 MW, the largest net power injection increase possible at Rockport is about 250 MW or less.

Short Circuit Interrupting Duties of Circuit Breakers

The short circuit duties of circuit breakers at Rockport 765 kV, Jefferson 765 kV, Sullivan 765 kV, and Breed 345 kV were checked with R44 in service. The largest increase in short circuit interrupting duties found was for the Rockport 765 kV breakers (about 3%), but the duties are well within the breaker capabilities. The largest short circuit duty found was for Breed 345 kV circuit breaker C1, but it only increased by 0.7%, from 90.0% to 90.7%.

PJM Feasibility Study Results

The PJM Feasibility Study identified two loading violations in AEP associated with R44. Both violations occur following the loss of Rockport-Jefferson 765 kV. The first violation is the loading of the Breed-Casey West 345 kV line. This line is an interconnection between

AEP and Ameren, of which Ameren is the majority owner. The rating of the line found in the power flow base case is based on Ameren rating practices and therefore this loading violation is a matter for Ameren to address. This will be done in the Impact Study. The second violation is the loading of the Darwin-Eugene 345 kV line. The present rating of this line for all conditions is its normal (continuous) rating because the line has not been checked for maximum sag. This violation can be eliminated by conducting a sag check and making any line improvements found necessary by the check. This evaluation will be done in the Impact Study.

However, these loading violations may not require that system improvements be proposed if the transmission network in the Rockport area remains in its present state (i.e., no transmission facilities are added). The reason for this conclusion is that with only two transmission outlets from the Rockport plant, the outage of a single outlet, and the outage of Rockport-Jefferson 765 kV is the more critical, requires that the power injection from Rockport 765 kV be reduced within thirty minutes of the outage in anticipation of a subsequent contingency while the first contingency is still not cleared. The generation reduction would be sufficient to eliminate the loading violations found by PJM.

System Upgrades and Costs

Determining effective and feasible upgrades to eliminate the negative impacts of connecting R44 to the Rockport Plant presented in this report is beyond the scope of the study. That analysis will be done in the Impact Study. A comprehensive determination of the upgrades requires detailed and extensive studies, in which neighboring companies that can be impacted by the system upgrades also participate. However, conceptual plans for potential system upgrades can be considered and assessed based on study results to date.

Power flow across a transmission path with a high X/R ratio (Rockport station X/R is about 62 with the Jefferson line out) is defined by the equation:

$$P_{12} = V_1 V_2 / X_{12} * \mathrm{SIN}\Theta_{12}$$

The maximum power across the transmission path is:

$$P_{MAX12} = V_1 V_2 / X_{12}$$

To increase maximum power, either transmission system voltages must be increased or transmission path reactance reduced. Maximum power can be maintained at its desired value by maintaining system voltage at desired levels.

Increasing reactive power support will increase transmission system voltage regulation performance. Installing a Static Var Compensator (SVC) is one means of increasing reactive power support and system voltage regulation in an area where installing additional generation sources is not an option, which appears to be the case in the southern Indiana vicinity of the Rockport Plant. However, increasing reactive power support alone may not be sufficient since it has been demonstrated that this solution may mask the potential for voltage collapse when operating near the steady state stability limit of an area. In the case of the Rockport area, adding an SVC also increases the complexity of system operation, which is already significantly high.

Adding series capacitors to existing transmission lines will reduce the path reactance. However, installing series capacitors can induce energy exchanges between the network and an electrically close turbine-generator shaft, which in turn can result in a sub-synchronous resonance condition. The resonance condition can cause shaft fatigue and damage. Adding series capacitors in the Rockport area will also increase the complexity of system operation.

The addition of transmission facilities will also increase maximum power from the Rockport area. The selected additions should reduce transmission path reactance so that maximum power will increase significantly. A significant increase in maximum power will mitigate the effects of inflation on the costs of future system upgrades to facilitate generation additions if any are contemplated. Two potential transmission facility additions are either a third Sullivan 765/345 kV transformer or a third 765 kV line from Rockport. The cost of each potential upgrade is as follows:

a. 765/345 kV, 1500 MVA Transformer Bank (3 1-Φ units) **$17,000,000**
b. One mile of 765 kV line **$5,000,000**

Potential terminals for a third 765 kV line from Rockport Plant are:

a. **Jefferson 765 kV (~110 miles)**
b. **Greentown 765 kV (~170 miles)**
c. **TVA network (~50-230 miles)**

Another potential 765 kV line addition is from the Sullivan station to the northern Illinois 765 kV network (~150 miles).

The selection of the most appropriate system upgrades will entail additional studies, and these will likely cost several multiples of the final feasibility study cost.

Summary

IPP R44 cannot be connected to the AEP Transmission System at Rockport as presently proposed due to maximum power injection limits at Rockport. Presently, only about 250 MW of additional generation can be accommodated at the Rockport injection point. Adding any more than 250 MW will require system improvements that can only be determined by additional studies that include dynamic stability analysis and power flow analysis of a broader scope than possible in a feasibility study. Also, the amount of additional generation that can be added at Rockport must also be confirmed by stability analysis, and the 250 MW value found in this study is only a preliminary result.