GE
Energy Consulting

PJM Renewable Integration Study

Task 3A Part C

Transmission Analysis

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imagination at work

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Acronyms and Nomenclatures

2% BAU	2% Renewable Penetration – Business-As-Usual Scenario
14% RPS	14% Renewable Penetration – RPS Scenario
20% LOBO	20% Renewable Penetration – Low Offshore Best Onshore Scenario
20% LODO	20% Renewable Penetration – Low Offshore Dispersed Onshore Scenario
20% HOBO	20% Renewable Penetration – High Offshore Best Onshore Scenario
20% HSBO	20% Renewable Penetration – High Solar Best Onshore Scenario
30% LOBO	30% Renewable Penetration – Low Offshore Best Onshore Scenario
30% LODO	30% Renewable Penetration – Low Offshore Dispersed Onshore Scenario
30% HOBO	30% Renewable Penetration – High Offshore Best Onshore Scenario
30% HSBO	30% Renewable Penetration – High Solar Best Onshore Scenario
AEPS	Alternative Energy Portfolio Standard
AGC	Automatic Generation Control
AWS/AWST	AWS Truepower
Bbl.	Barrel
BAA	Balancing Area Authority
BAU	Business as Usual
BTU	British Thermal Unit
CA	Intertek AIM's Cycling⬍Advisor™ tool
CAISO	California Independent System Operator
CC/CCGT	Combined Cycle Gas Turbine
CEMS	Continuous Emissions Monitoring Systems
CF	Capacity Factor
CO2	Carbon Dioxide
CV	Capacity Value
DA	Day-Ahead
DR	Demand Response
DSM	Demand Side Management
EI	Eastern Interconnection

EIPC	Eastern Interconnection Planning Collaborative
ELCC	Effective Load Carrying Capability
ERCOT	Electricity Reliability Council of Texas
EST	Eastern Standard Time
EUE	Expected Un-served Energy
EWITS	Eastern Wind Integration and Transmission Study
FERC	Federal Energy Regulatory Commission
FLHR	Full Load Heat Rate
FSA	PJM Facilities Study Agreement
GE	General Electric International, Inc. / GE Energy Consulting
GE MAPS	GE's "Multi Area Production Simulation" model
GE MARS	GE's "Multi Area Reliability Simulation" model
GT	Gas Turbine
GW	Gigawatt
GWh	Gigawatt Hour
HA	Hour Ahead
HSBO	High Solar Best Onshore Scenarios
HOBO	High Offshore Best Onshore Scenarios
HR	Heat Rate
HVAC	Heating, Ventilation, and Air Conditioning
IPP	Independent Power Producers
IRP	Integrated Resource Planning
ISA	PJM Interconnection Service Agreement
ISO-NE	Independent System Operator of New England
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
lbs	Pounds (British Imperial Mass Unit)
LDC	Load Duration Curve

LM	Intertek AIM's Loads Model ™ tool
LMP	Locational Marginal Prices
LNR	Load Net of Renewable Energy
LOBO	Low Offshore Best Onshore Scenarios
LODO	Low Offshore Dispersed Onshore Scenarios
LOLE	Loss of Load Expectation
MAE	Mean-Absolute Error
MAPP	Mid-Atlantic Power Pathway
MMBtu	Millions of BTU
MVA	Megavolt Ampere
MW	Megawatts
MWh	Megawatt Hour
NERC	North American Electric Reliability Corporation
NOx	Nitrogen Oxides
NREL	National Renewable Energy Laboratory
NWP	"Numerical Weather Prediction" model
O&M	Operational & Maintenance
PATH	Potomac Appalachian Transmission Highline
PJM	PJM Interconnection, LLC.
PPA	Power Purchase Agreement
PRIS	PJM Renewable Integration Study
PRISM	Probabilistic Reliability Index Study Model
PROBE	"Portfolio Ownership & Bid Evaluation Model" of PowerGEM
PSH	Pumped Storage Hydro
PV	Photovoltaic
REC	Renewable Energy Credit
Rest of EI	Rest of Eastern Interconnection
RPS	Renewable Portfolio Standard
RT	Real Time

RTEP	Regional Transmission Expansion Plan
SC/SCGT	Simple Cycle Gas Turbine
SCUC/EC	Security Constrained Unit Commitment / Economic Dispatch
SOx	Sulfur Oxides
ST	Steam Turbine
TARA	"Transmission Adequacy and Reliability Assessment" software of PowerGEM
UCT	Coordinated Universal Time
VOC	Variable Operating Cost
WI	Western Interconnection

1 Transmission Analysis

1.1 Purpose of Transmission Overlay Analysis

The purpose of this phase of the study was for PowerGEM to create a transmission overlay that resolved the most significant reliability and congestion issues for each renewable scenario. The overlay was developed based on two separate drivers. First a transmission overlay was created to resolve any reliability issues caused by the addition of the renewable resources. A congestion study was then performed using this overlay to determine if any areas of the PJM system had significant congestion. An additional transmission overlay was then created to address any flowgates resulting in congestion greater than a certain threshold. The final transmission overlay was the combination of the reliability driven and congestion driven overlays for each scenario.

While transmission overlays identified here resolved the most significant reliability and congestion issues for each scenario, some potentially significant transmission costs were not within the scope of this study, e.g., 1) generator interconnection costs (wind and solar units were located at nearest EHV bus), 2) upgrades to resolve overloads at voltage levels below 230kV, and 3) upgrades needed to resolve voltage violations. Also, there is still significant congestion remaining in some scenarios (up to $6.3B/year).

1.2 Transmission System Upgrades

The transmission model was built upon the 2016 and 2017 Regional Transmission Expansion Plan (RTEP) models provided by PJM. New lines and other transmission upgrades were added to the transmission models for each study scenario to serve the increased load and generation resources. Given that the output of wind and solar resources inherently varies by time of day and season of year, the traditional transmission expansion planning methods were augmented by production cost analysis to ensure adequate transmission capacity without overbuilding. Some wind plants and thermal plants share common transmission corridors, and since wind plants are not dispatchable, it is not appropriate to size those corridors to accommodate simultaneous maximum output from both wind and thermal plants.

The transmission expansion process involved the following steps:

- Security-constrained optimal power flow analysis to identify transmission paths that are overloaded under contingency conditions and cannot be relieved by adjusting the dispatch.

- Generator deliverability analysis with wind and solar plant loaded to 100% of capacity value, to identify reliability problems that required transmission upgrades.
- Generator deliverability analysis with wind and solar plant loaded to 100% of energy value, to identify flowgates that could be overloaded and therefore should be monitored in production cost analysis.
- Production cost analysis to quantify annual transmission path utilization and congestion, and to identify paths with excessive congestion.

These steps were performed iteratively on each scenario to design a set of transmission upgrades that would achieve deliverability and reliability objectives without excessive congestion. Transmission capacity was increased until the largest contribution to congestion costs by a constrained element between two nodes with highest and lowest average annual LMP in the system was $5/MWh, averaged across the year.

1.3 System Model and Analysis Description

PJM provided PowerGEM a 2017 Regional Transmission Expansion Plan (RTEP) summer model to be used for peak load reliability analysis and a 2016 RTEP model with load levels adjusted to a 2026 60% load level to be used for light load reliability analysis. For both models, PJM also provided a single contingency file that matched the corresponding load flow model.

The following modifications were subsequently made to these models at PJM's request to better align the models with more recent transmission topology and generation portfolio changes.

- Removed the PATH backbone project
- Removed the MAPP backbone project
- Modeled generation offline based on retirement announcements in late 2011 / early 2012

For the peak load study, the generator deliverability analysis was completed on the 2017 RTEP model with the results extrapolated to the year 2026. All facilities greater than 230 kV were monitored and overloads were based on pre-contingency and single contingency loadings with the ratings set to the conductor rating. Solar and wind generation was modeled at the capacity values at each site as determined by GE. In general, the average capacity factor for wind was around 38% and solar was 18%. Modeling the solar and wind generation at individual sites as opposed to netting against load provides a more realistic representation since netting against load has the effect of missing the transmission impacts associated with specific MW injections.

For the light load study, the following generation assumptions were applied by PowerGEM in the 2016 RTEP model with a 2026 60% load level:

- Wind generation was modeled at 70% of nameplate with fixed output
- Solar generation was modeled at the capacity value as determined by GE for each individual site – the average solar capacity factor was 18%.
- Nuclear generation was modeled at 100% of nameplate and must run
- Coal was modeled at Pmin with availability to run up to Pmax.
- All natural gas generation and CTs were modeled as offline with the availability to run up to Pmax

The system was studied using a security constrained optimal power flow where generation was allowed to move (within the limits imposed in the set-up described previously) to relieve any pre-contingency or single contingency overloads. Any overloads that could not be relieved via generation dispatch were considered an issue and a transmission overlay was developed to address the problem. Economics were not a consideration for the light load reliability evaluation. The economic input for the transmission overlay was provided via the GE MAPS simulations.

After the reliability driven transmission overlay was developed based on the identified peak and light load overloads, both the peak and light load studies were redone to assure no significant overloads remained.

PowerGEM also took the 2017 RTEP model with transmission overlay and performed a generator deliverability analysis with wind and solar modeled at 100% of nameplate to develop additional flowgates to be used in the MAPS simulations. All flowgates loaded greater than 75% were provided to GE to include in the GE MAPS simulations. In situations where a monitored facility was identified for numerous contingencies, the flowgate resulting in the highest loading was selected.

GE performed a GE MAPS simulation for each scenario with the transmission overlays that were developed to resolve all reliability problems. GE MAPS identified congestions that resulted in $5/MWh price difference between the highest generation bus LMP and the lowest generation bus LMP, which were then passed to PowerGEM and the transmission overlay was further upgraded to mitigate the identified congestion issues.

1.4 Summary of Transmission Overlay for all Scenarios

Table 1-1 provides a summary of the circuit miles, a planning level cost estimate for the transmission overlays and the total remaining congestion for each scenario. All planning level cost estimates were provided by PJM and were similar to those used in the Eastern Interconnection Planning Collaborative Phase II Report.

In general, when developing the transmission overlay an approach was taken to minimize the cost of transmission upgrades that would be required. If a constrained circuit had a low rating for the voltage class (such as 450 MVA at 230 kV or 900 MVA at 345 kV) then reconductoring was assumed as the upgrade. If a constrained circuit had a rating that was on the high end for the voltage class (such as 1000 MVA at 230 kV or 1800 MVA at 345 kV) a second parallel circuit was assumed as the upgrade. When numerous 345 kV constraints were in the same geographical area, a new 765 kV circuit was considered as the upgrade. If one new 765 kV circuit did not resolve all of the issues in the area then a second 765 kV was added. The goal of this study was not to develop an optimized transmission overlay but rather to develop a transmission overlay that would be indicative of what would be required to support the projected renewable resource additions for each scenario.

The costs in Table 1-1 do not include any direct connection facilities and the associated costs needed to interconnect the renewable resources. This includes, in the case of offshore wind projects, that no transmission component is included to deliver the power from the off shore site to the point of interconnection since this is a direct connection facility. Also, Table 1-1 only includes system upgrades to resolve thermal overloads on facilities greater than 230 kV. No voltage or stability analysis was performed.

Table 1-1: Summary of New Transmission Lines and Upgrades for Study Scenarios

Scenario	765 kV New Lines (Miles)	765 kV Upgrades (Miles)	500 kV New Lines (Miles)	500 kV Upgrades (Miles)	345 kV New Lines (Miles)	345 kV Upgrades (Miles)	230 kV New Lines (Miles)	230 kV Upgrades (Miles)	Total (Miles)	Total Cost (Billion)	Total Congestion Cost (Billion)
2% BAU	0	0	0	0	0	0	0	0	0	$0	$1.9
14% RPS	260	0	42	61	352	35	0	4	754	$3.7	$4.0
20% Low Offshore Best Onshore	260	0	42	61	416	122	0	4	905	$4.1	$4.0
20% Low Offshore Dispersed Onshore	260	0	42	61	373	35	0	49	820	$3.8	$4.9
20% High Offshore Best Onshore	260	0	112	61	363	122	17	4	939	$4.4	$4.3
20% High Solar Best Onshore	260	0	42	61	365	122	0	4	854	$3.9	$3.3
30% Low Offshore Best Onshore	1800	0	42	61	796	129	44	74	2946	$13.7	$5.2
30% Low Offshore Dispersed Onshore	430	0	42	61	384	166	44	55	1182	$5.0	$6.3
30% High Offshore Best Onshore	1220	0	223	105	424	35	14	29	2050	$10.9	$5.3
30% High Solar Best Onshore	1090	0	42	61	386	122	4	4	1709	$8	$5.6

General observations concerning the transmission upgrades include:

- Similar amounts of transmission upgrades are required for the 14% RPS Scenario and all the 20% scenarios.
- The 30% scenarios have significant differences in the levels of transmission upgrades required.
- The 30% LOBO scenario required the most transmission upgrades. This scenario has a huge concentration of wind resources in Illinois and Indiana. Increased transmission capacity is required to deliver that wind energy from the wind-rich region to the major PJM load centers.
- The 30% HOBO has a mix of offshore and onshore wind resources. The onshore wind resources are mostly located in Illinois, Indiana and Ohio, and require transmission upgrades to deliver that energy to load centers. Much of the offshore wind is in North Carolina, Virginia and New Jersey, and they also require new transmission to connect to major load centers. However, the overall transmission requirement is lower than the 30% LOBO case which has more wind in western PJM.
- The 30% LODO has wind resources spread more evenly across the PJM footprint, and therefore requires significantly fewer transmission upgrades.
- For this study, solar resources were assumed to be mostly in large population centered, in and surrounding major cities. Thus, transmission upgrades for the 30% HSBO scenario were lower than the scenarios with wind resources at the best onshore and offshore sites, which are remotely located from load centers.

Congestion costs for each scenario are summarized in the table.

1.5 Transmission Overlay Results for 14% RPS Scenario

The transmission constraints driving the transmission overlay for the 14% RPS scenario are shown in Table 1-2 and the transmission overlay to resolve the constraints is shown in Table 1-3. Figure 1-2 through Figure 1-7 illustrate the constraints and corresponding transmission overlays graphically and Figure 1-1 is a legend for the geographic maps.

The estimated cost of the transmission overlay for the 14% RPS scenario is $3.7 billion and involved more than 750 miles of new and upgraded transmission. About 71% ($2.6 billion) of the transmission overlay was needed to provide an outlet for 20 GW of western wind projects in ComEd and AEP to eastern load centers. Another 18% ($0.7 billion) was needed to provide an outlet for 4 GW of offshore wind along the NJ, DE, MD and VA coast. The remaining 11% of transmission upgrades were dispersed throughout the PJM footprint.

The 14% RPS transmission overlay was used as the starting point transmission model for all 20% and 30% scenarios. Expanded transmission overlays were developed for the 20% and 30% scenarios based on any identified reliability and congestion issues in those models.

Table 1-2: Transmission Constraints for 14% RPS Scenario

Transmission Constraints
Jacksons Ferry – Antioch 500 kV
Cloverdale – Lexington 500 kV
Quad Cities – Rock Creek 345 kV
Loretto – Pontiac 345 kV
Braidwood – East Frankfort 345 kV
La Salle – Plano 345 kV
Plano – Electric Jct. 345 kV
Dresden – Elwood 345 kV
Powerton – Goodings Grove 345 kV
Cherry Valley – Silver Lake 345 kV
Byron – Cherry Valley 345 kV
Lee County – Byron 345 kV
Lee County – Nelson 345 kV
Cordova – Nelson 345 kV
Dumont – Stillwell 345 kV
Breed – Wheatland 345 kV
Keystone – Sorenson 345 kV
Allen – Robinson 345 kV
Nelson – Electric Jct. 345 kV
Olive – Green Acres 345 kV
Kammer – West Bellaire 345 kV
South Canton – Star 345 kV
Johnstown – Bear Rock – Altoona 230 kV
Milford – Steele 230 kV
Milford – Cedar Creek 230 kV
Cedar Creek – Red Lion 230 kV

Table 1-3: Transmission Overlay for 14% RPS Scenario

Transmission Overlay Due to Reliability
Two Red Lion – Cedar Creek 500 kV
2nd South Canton – Star 345 kV
2nd Kammer – West Bellaire 345 kV
2nd Allen – Robinson Park 345 kV
3rd Keystone – Sorenson 345 kV
3rd Byron – Cherry Valley 345 kV
3rd Plano – Electric Jct. 345 kV
Lee County - Plano 765 kV
La Salle – Plano 765 kV
La Salle – Powerton 345 kV
La Salle – Pontiac 345 kV
Transmission Overlay Due to Congestion
2nd Lee County - Plano 765 kV
Quad Cities – Lee County 345 kV
2nd Stillwell – Dumont 345 kV
Plano – Wilton Center 765 kV
2nd Cherry – Silver Lake 345 kV
2nd Wilton Center – Dumont 765 kV
Reconductor Cloverdale – Lexington 500 kV
Replace Cloverdale 500/345 kV transformers
Reconductor Jackson Ferry – Antioch 500 kV
Reconductor Breed – Wheatland 345 kV
Reconductor Johnstown – Bear Rock – Altoona 230 kV

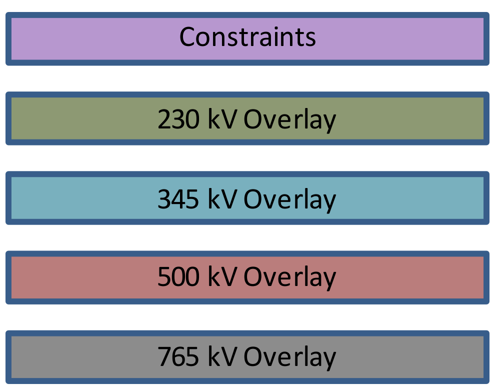

Figure 1-1: Legend for Figure 1-2 through Figure 1-7

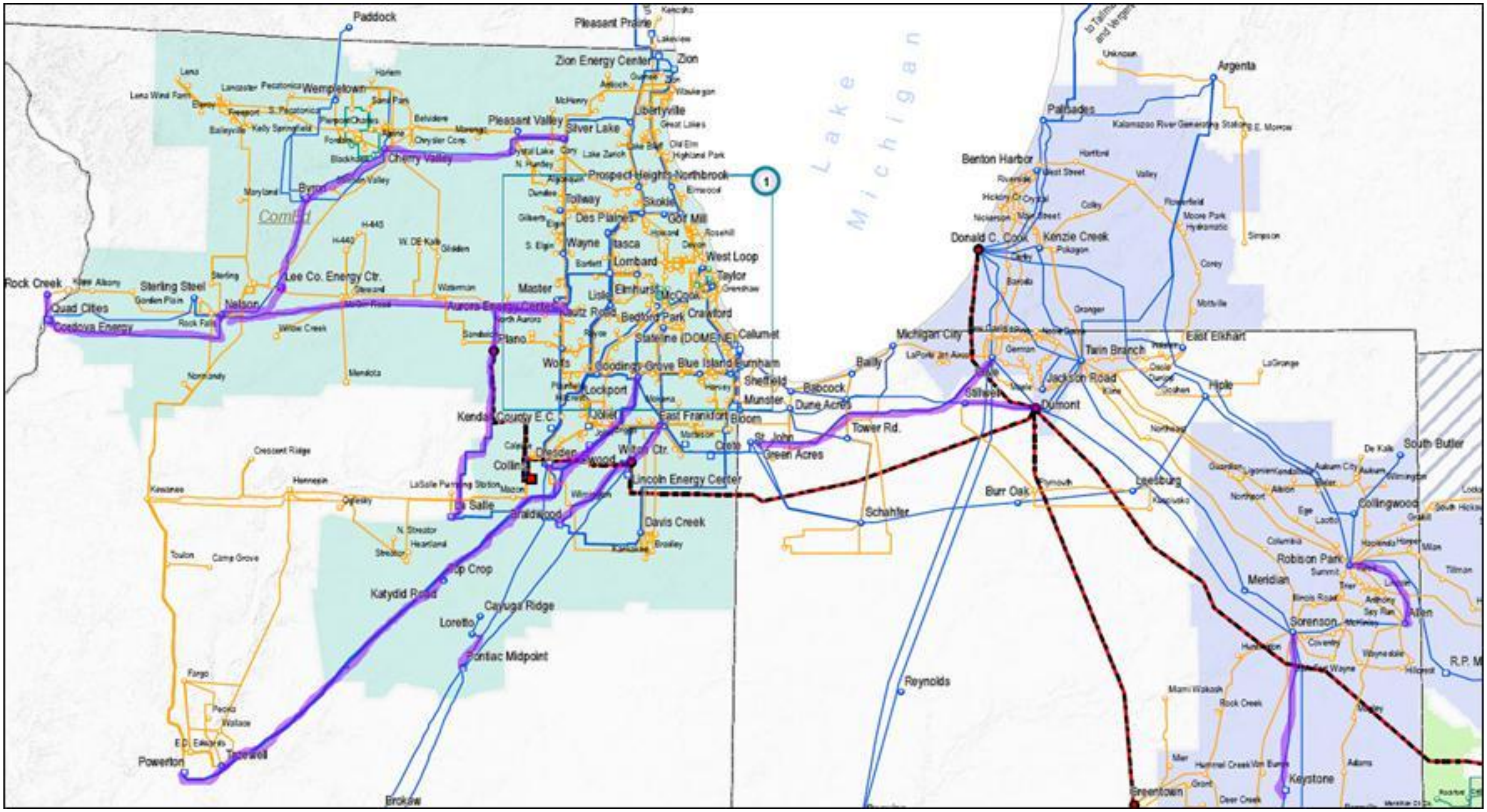

Figure 1-2: 14% RPS Transmission Constraints – ComEd / Western AEP

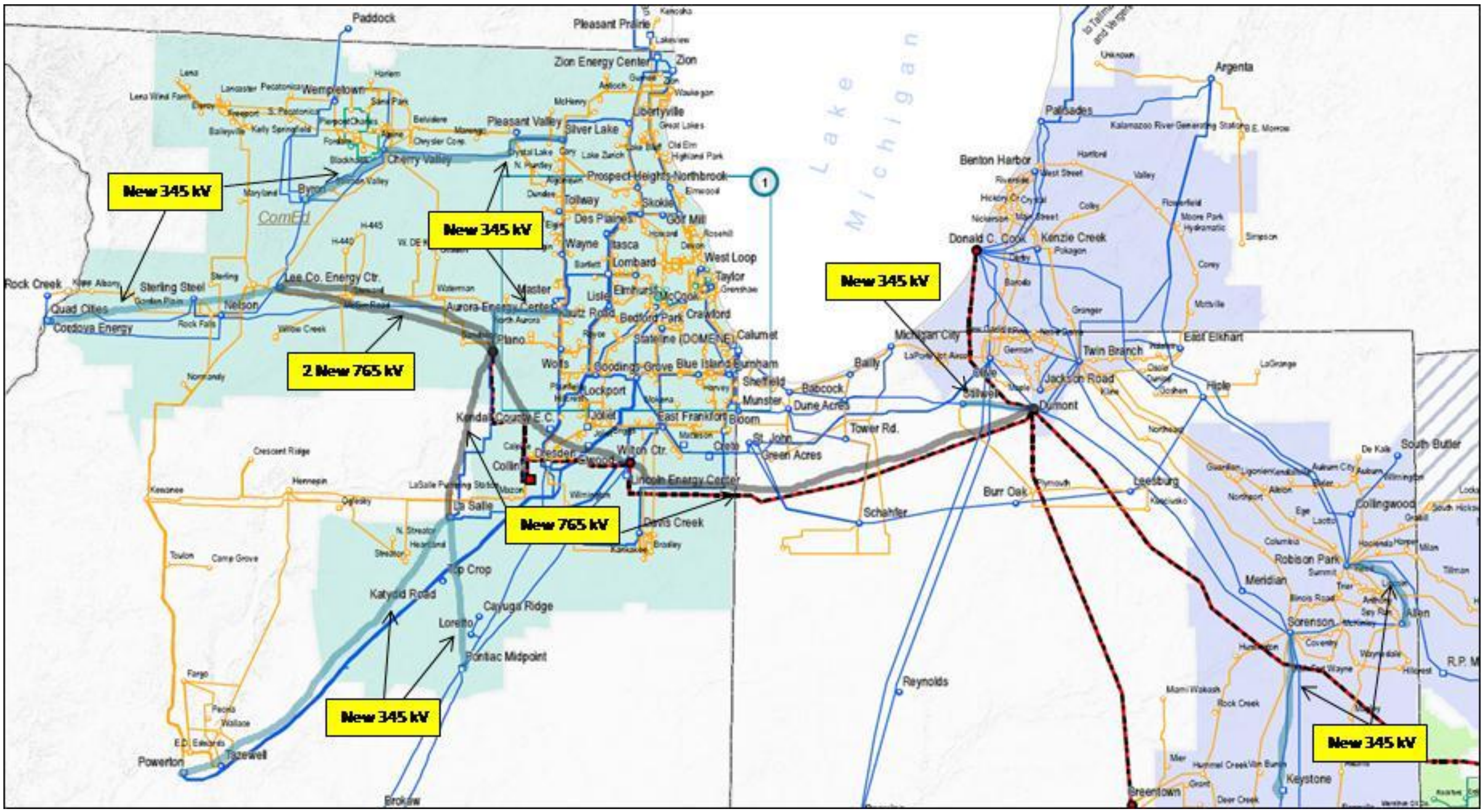

Figure 1-3: 14% RPS Transmission Overlay – ComEd / Western AEP

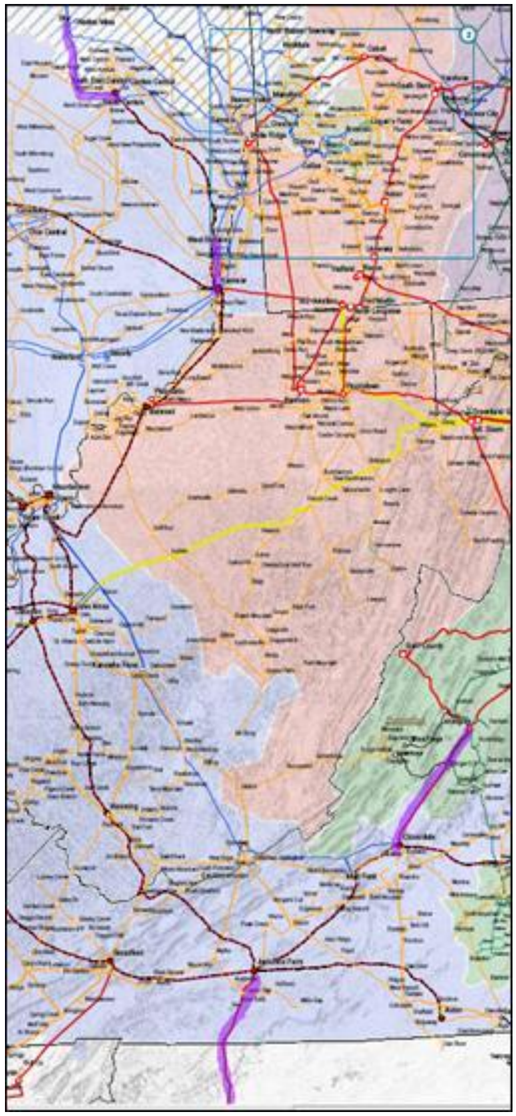

Figure 1-4: 14% RPS Transmission Constraints – Eastern AEP / ATSI / Dominion

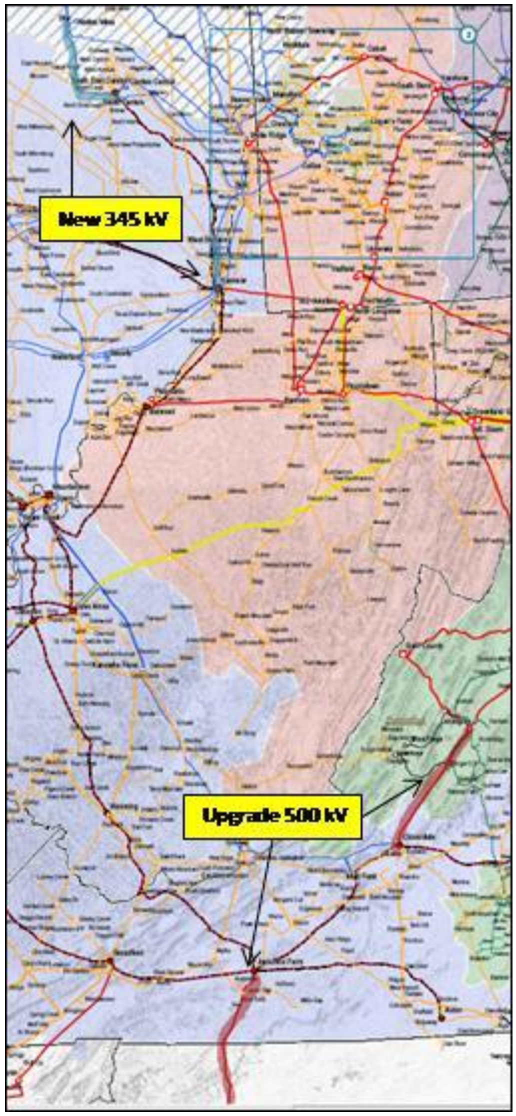

Figure 1-5: 14% RPS Transmission Overlay – Eastern AEP / ATSI / Dominion

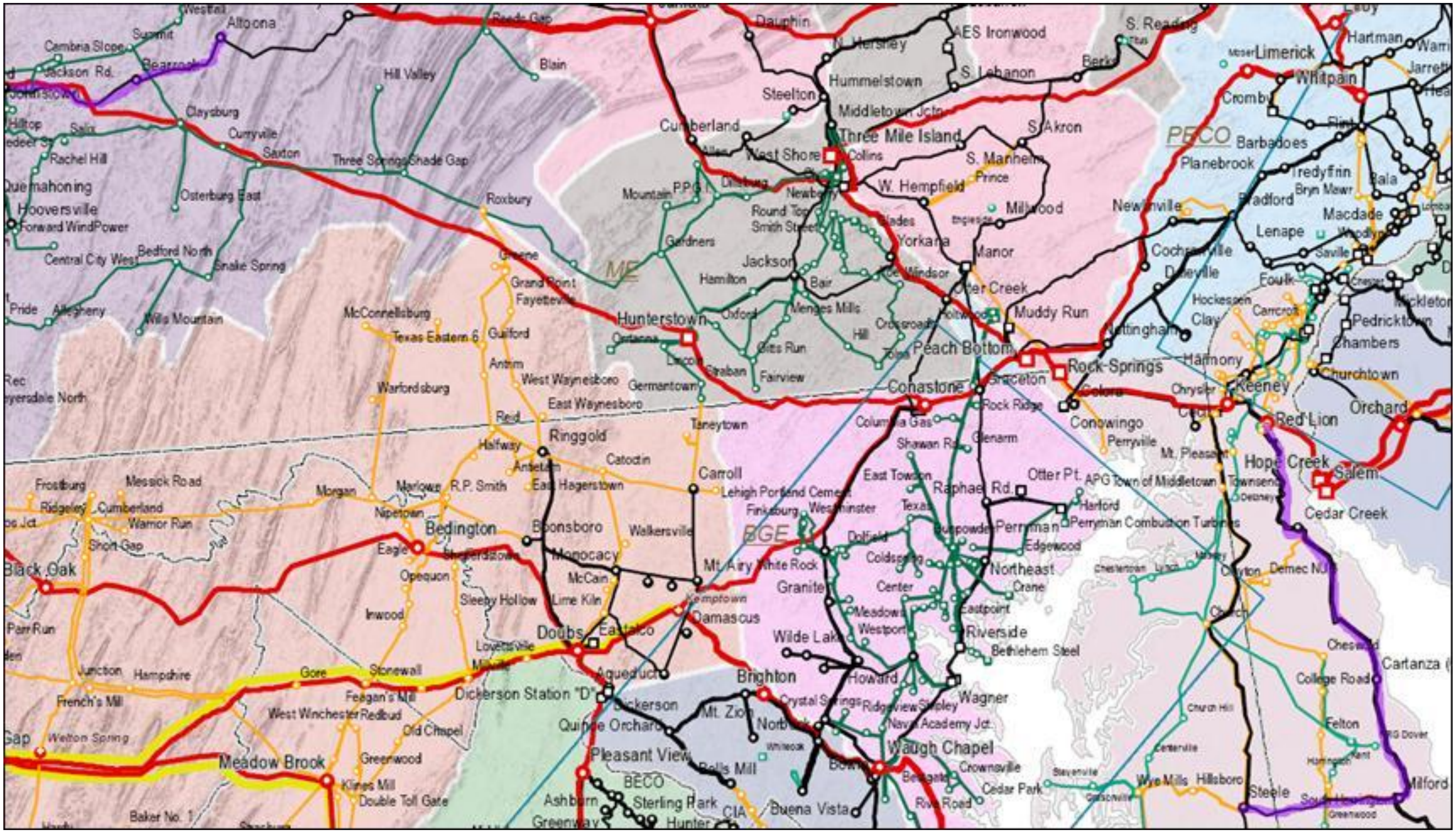

Figure 1-6: 14% RPS Transmission Constraints – Mid-Atlantic Region

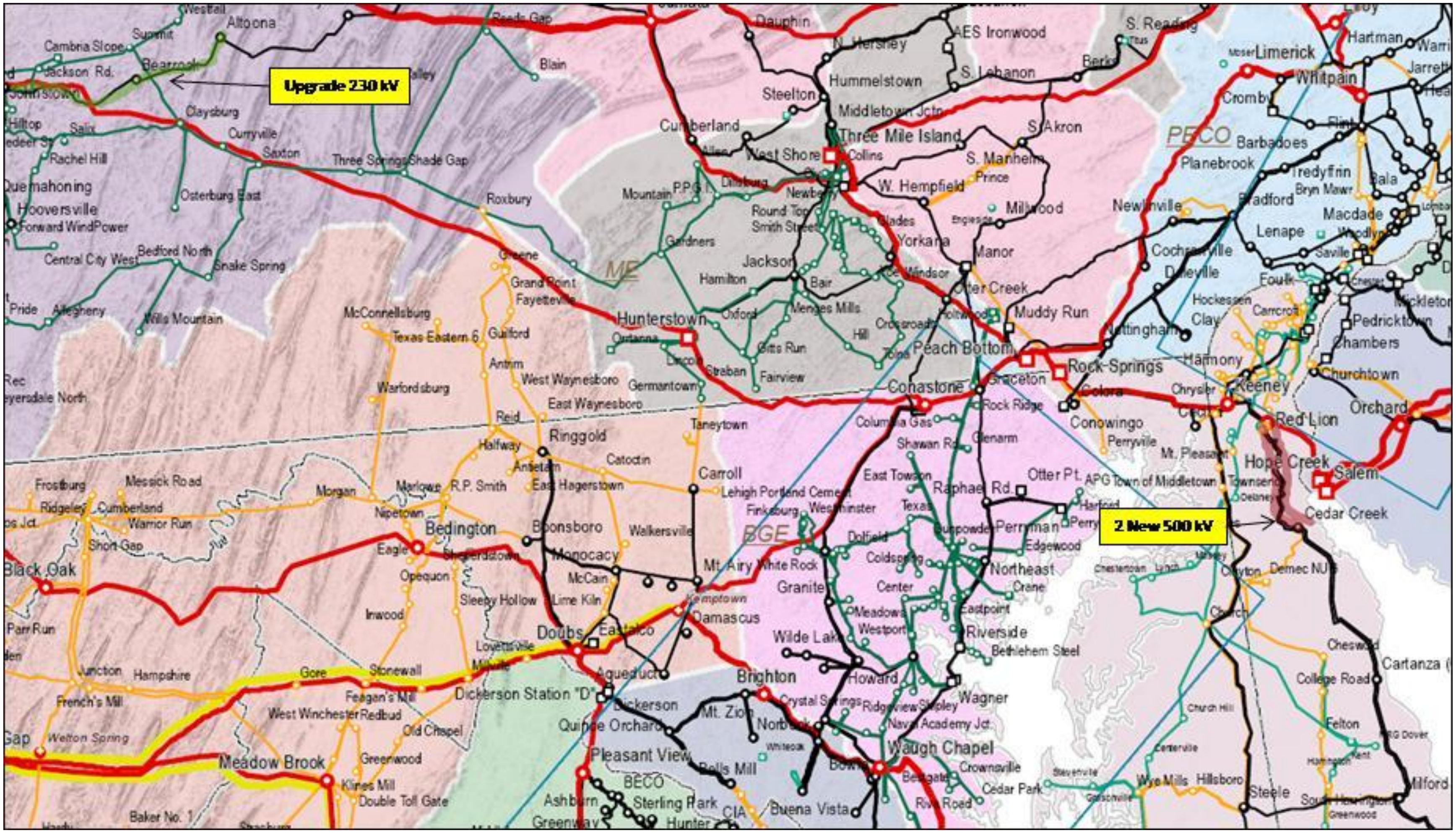

Figure 1-7: 14% RPS Transmission Overlay – Mid-Atlantic Region

1.6 Transmission Overlay Results for 20% Scenarios

The transmission overlay estimated cost and miles of new and upgraded transmission for the four 20% scenarios are shown in Table 1-4.

Table 1-4: Summary of Transmission Upgrade Miles and Cost for 20% Scenarios

Scenario	Total Miles of New and Upgraded Transmission	Total Cost (Billion)
20% Low Offshore Best Onshore	905	$4.1
20% Low Offshore Dispersed Onshore	820	$3.8
20% High Offshore Best Onshore	939	$4.4
20% High Solar Best Onshore	854	$3.9

Total upgrade costs ranged from $3.8 billion to $4.4 billion. The range in upgrade costs and total upgrade expenditure for the 20% scenarios was much less than the 30% scenarios. This was primarily because the renewable resource additions between the 14% RPS scenario and the 20% scenarios were significantly less than the 30% scenarios and therefore the 20% scenarios could use some of the headroom provided by the 14% RPS overlay. Table 1-5 through Table 1-12 include the transmission constraints and overlays for the 20% scenarios. Appendix A of this section contains the geographic maps for the 20% scenarios.

Table 1-5: Transmission Constraints for 20% LOBO Scenario

Dresden – Elwood 345 kV
Brokaw - Pontiac 345 kV
Quad - Sub 91 345 kV
Plano 765/345 kV
Quad - Rock Cities 345 kV
Kanawha River – Matt Funk 345 kV
E. Frankfort – Crete 345 kV

Table 1-6: Transmission Overlay for 20% LOBO Scenario

Transmission Overlay Due to Reliability
2nd Dresden – Elwood 345 kV
2nd Brokaw - Pontiac 345 kV
Transmission Overlay Due to Congestion
2nd Quad - Sub 91 345 kV
2nd Quad - Rock Cities 345 kV
Reconductor Kanawha R. – M. Funk 345 kV
2nd E. Frankfort – Crete 345 kV
New Plano 765/345 kV

Table 1-7: Transmission Constraints for 20% LODO Scenario

Byron - Cherry Valley 345 kV
Valley 500/230 kV
Altoona – Raystown 230 kV
Raystown – Lewistown 230 kV

Table 1-8: Transmission Overlay for 20% LODO Scenario

Transmission Overlay Due to Congestion
2nd Byron - Cherry Valley 345 kV
Replace Valley 500/230 kV
Reconductor Altoona – Raystown 230 kV
Reconductor Raystown – Lewistown 230 kV

Table 1-9: Transmission Constraints for 20% HOBO Scenario

Fentress – Thrasher 230 kV
Fentress – Landstown 230 kV
Fentress 500/230 kV
Thrasher - Huntsman 230 kV
Huntsman - Yadkin 230 kV
Shawboro - Eliz CT 230 kV
TMI 500/230 kV
Everetts - Greenville 230 kV
Quad - Sub 91 345 kV
Kanawha River – Matt Funk 345 kV
Plano 765/345 kV

Table 1-10: Transmission Overlay for 20% HOBO Scenario

Transmission Overlay Due to Reliability
2nd Fentress – Thrasher 230 kV
2nd Fentress – Landstown 230 kV
Replace Fentress 500/230 kV
New Fentress - Carson 500 kV
2nd TMI 500/230 kV
Transmission Overlay Due to Congestion
2nd Everetts – Greenville 230 kV
2nd Quad - Sub 91 345 kV
Reconductor Kanawha R. – M. Funk 345 kV
New Plano 765/345 kV

Table 1-11: Transmission Constraints for 20% HSBO Scenario

Plano 765/345 kV
Kanawha River – Matt Funk 345 kV
E. Frankfort – Crete 345 kV

Table 1-12: Transmission Overlay for 20% HSBO Scenario

Transmission Overlay Due to Congestion
New Plano 765/345 kV
Reconductor Kanawha R. – M. Funk 345 kV
2nd E. Frankfort – Crete 345 kV

1.7 Transmission Overlay Results for 30% Scenarios

The transmission overlay estimated cost and miles of new and upgraded transmission for the four 30% scenarios are shown in Table 1-13.

Table 1-13: Summary of Transmission Upgrade Miles and Cost for 30% Scenarios

Scenario	Total Miles of New and Upgraded Transmission	Total Cost (Billion)
30% Low Offshore Best Onshore	2946	$13.7
30% Low Offshore Dispersed Onshore	1182	$5.0
30% High Offshore Best Onshore	2050	$10.9
30% High Solar Best Onshore	1709	$8.0

Total upgrade costs range from $5 billion to $13.7 billion with the higher upgrade costs required for the scenarios with the more concentrated wind generation profiles. For example, the highest upgrade costs were for the 30% Low Offshore Best Sites Onshore scenario which had 54 GW of wind generation added in Illinois and Indiana.

Additional information for each 30% scenario is contained in the following sections. Appendix B of this section contains the geographic maps for the 30% scenarios.

1.7.1 Transmission Overlay Results for 30% LOBO Scenario

As previously mentioned, the 30% LOBO scenario had the most expensive upgrade cost at $13.7 billion. This is primarily due to a high concentration of wind projects (54 GW) in Illinois and Indiana which resulted in extensive amounts of new 765 kV and 345 kV transmission circuits ($11.7 billion) which were needed to provide an outlet for the renewable generation. The transmission constraints driving the transmission overlay for the 30% LOBO scenario are shown in Table 1-14and the transmission overlay to resolve the constraints is shown in Table 1-15.

Table 1-14: Transmission Constraints for 30% LOBO Scenario

Plano – Collins 765 kV	Conastone - Emory Grove 230 kV
Collins – Wilton Center 765 kV	Glade - Warren 230 kV
Wilton Center – Dumont 765 kV	Seward - Johnstown 230 kV
Marysville – Kammer 765 kV	Seward 230/115 kV
Mountaineer – Belmont 765 kV	Homer City 345/230 kV
Dresden – Elwood 345 kV	Watercure - Homer City 345 kV
Pontiac – Dresden 345 kV	Pontiac 765/345 kV
Pontiac – Wilton Center 345 kV	La Salle 765/345 kV
Lee County – Nelson 345 kV	Breed - Casey 345 kV
Dresden – Electric Jct. 345 kV	Jefferson 765/345 kV
E. Frankfort – Crete 345 kV	Pleasant View - Ashburn 230 kV
Crete – St. John 345 kV	Kammer 765/500 kV
Reynolds – Olive 345 kV	Fentress 500/230 kV
Stillwell – Dumont 345 kV	Bayshore - Monroe 345 kV
Munster – Burnham 345 kV	Convoy - R60 345 kV
Many 345 kV circuit in AEP	Bremo - Powhatan 230 kV
Many 345 kV circuits in ComEd	Everetts - Greenville 230 kV
Quad – Sub 91 345 kV	Pleasant View 500/230 kV
Fentress – Thrasher 230 kV	Chesterfield - Tyler 230 kV
Fentress – Landstown 230 kV	Person - Halifax 230 kV
Valley 500/230 kV	Powhatan - Judes 230 kV
Kanawha River – Matt Funk 345 kV	Zion - Pleasant Prairie 345 kV
New Freedom - Monroe 230 kV	

Table 1-15: Transmission Overlay for 30% LOBO Scenario

Transmission Overlay Due to Reliability	Transmission Overlay Due to Congestion
Quad Cities – La Salle 765 kV	3rd Seward 230/115 kV
Two La Salle – Pontiac 765 kV	Replace Homer City 345/230 kV
Two Pontiac – Greentown 765 kV	2nd Watercure - Homer City 345 kV
Two Greentown – Vassell 765 kV	New Pontiac 765/345 kV
Two New Vassell – Star 765 kV	New La Salle 765/345 kV
Star – Keystone 765 kV	2nd Breed - Casey 345 kV
Star – S. Canton 765 kV	New Jefferson 765/345 kV
Pontiac – Sullivan 765 kV	Reconductor Pl. View - Ashburn 230 kV
Sullivan – Jefferson 765 kV	New Kammer 765/550 kV
Jefferson – Belmont 765 kV	Replace Fentress 500/230 kV
2nd Lee County – Nelson 345 kV	2nd Eugene - Bunsonville 345 kV
2nd Reynolds – Olive 345 kV	2nd T94A - Palisades 345 kV
2nd Quad Cities – Rock Creek 345 kV	2nd Bayshore - Monroe 345 kV
2nd Marysville – Hyatt 345 kV	2nd Olive - Dumont 345 kV
	2nd Brokaw - Pontiac 345 kV
	Reconductor Convoy - R60 345 kV
	2nd Everetts – Greenville 230 kV
	2nd Pleasant View 500/230 kV
	Reconductor Chesterfield - Tyler 230 kV
	Reconductor Person - Halifax 230 kV
	Reconductor Powhatan - Judes 230 kV
	2nd Zion - Pleasant Prairie 345 kV
	2nd Quad – Sub 91 345 kV
	2nd Fentress – Thrasher 230 kV
	2nd Fentress – Landstown 230 kV
	Replace Valley 500/230 kV
	Reconductor Kanawha R. – M. Funk 345 kV
	2nd New Freedom - Monroe 230 kV
	3rd Conastone - Emory Grove 230 kV
	Reconductor Glade - Warren 230 kV
	Reconductor Seward - Johnstown 230 kV

1.7.2 Transmission Overlay Results for 30% LODO Scenario

The 30% LODO scenario had the lowest transmission upgrade costs of the 30% scenarios primarily because the renewable resources were more distributed throughout the PJM footprint allowed the use of existing transmission headroom in certain areas without additional transmission upgrades. The transmission constraints driving the transmission overlay for the 30% LODO scenario are shown in Table 1-16 and the transmission overlay to resolve the constraints is shown in Table 1-17.

Table 1-16: Transmission Constraints for 30% LODO Scenario

Dresden – Elwood 345 kV
Pontiac – Wilton Center 345 kV
La Salle – Plano 345 kV
E. Frankfort – Braidwood 345 kV
Plano – Electric Jct. 345 kV
Marysville – Hyatt 345 kV
Pearson – Halifax 230 kV
Clover – Halifax 230 kV
Altoona – Raystown 230 kV
Raystown – Lewistown 230 kV
Quad – Sub 91 345 kV
Everetts – Greenville 230 kV
Fentress – Thrasher 230 kV
Fentress – Landstown 230 kV
Valley 500/230 kV
Kanawha River – Matt Funk 345 kV
Davis Besse – Beaver 345 kV

Table 1-17: Transmission Overlay for 30% LODO Scenario

Transmission Overlay Due to Reliability
LaSalle – Pontiac 765 kV
Two Pontiac 765/345 kV
2nd Marysville – Hyatt 345 kV
2nd Pearson – Halifax 230 kV
Pontiac – Greentown 765 kV
2nd Clover – Halifax 230 kV
Transmission Overlay Due to Congestion
Reconductor Altoona – Raystown 230 kV
Reconductor Raystown – Lewistown 230 kV
2nd Quad – Sub 91 345 kV
2nd Everetts – Greenville 230 kV
2nd Fentress – Thrasher 230 kV
2nd Fentress – Landstown 230 kV
Replace Valley 500/230 kV
Reconductor Kanawha R. – M. Funk 345 kV
Reconductor Davis Besse – Beaver 345 kV

1.7.3 Transmission Overlay Results for 30% HOBO Scenario

The 30% HOBO scenario had a total of 38 GW of offshore wind along the NJ, DE, MD and VA coast which resulted in significant transmission build out in Dominion ($5.2 billion) and the Mid-Atlantic Region ($1.6 billion) to provide an outlet for the generation.

The transmission constraints driving the transmission overlay for the 30% HOBO scenario are shown in Table 1-18 and the transmission overlay to resolve the constraints is shown in Table 1-19.

Table 1-18: Transmission Constraints for 30% HOBO Scenario

Fentress – Septa 500 kV
Septa – Surry 500 kV
Septa – Carson 500 kV
Yadkin – Suffolk 500 kV
Surry - Chickahominy 500 kV
Chickahominy – Elmont 500 kV
Elmont – Ladysmith 500 kV
Ladysmith – North Anna 500 kV
North Anna – Morrisville 500 kV
Keeney – Red Lion 500 kV
Keeney – Rock Springs 500 kV
Rock Springs – Peach Bottom 500 kV
Red Lion – Hope Creek 500 kV
Cedar Creek – Red Lion 500 kV
Red Lion 500/230 kV
Peach Bottom 500/230 kV
Pontiac – Loretto 345 kV
Loretto – Wilton Center 345 kV
Many 230 kV circuits in Dominion
Keeney – Red Lion 230 kV
Harmony – Keeney 230 kV
Linwood – Chichester 230 kV
Seward 230/115 kV
Lee County – Byron 345 kV
Fentress 500/230 kV
Benton – Cook 345 kV
Seward – Johnstown 230 kV

Table 1-19: Transmission Overlay for 30% HOBO Scenario

Transmission Overlay Due to Reliability
Two Axton – Fentress 765 kV
Two Joshua Falls – Fentress 765 kV
Four Fentress 765/500 kV
Two Fentress – Suffolk 500 kV
Rebuild Surry – Chickahominy 500 kV
2nd Fentress – Thrasher 230 kV
2nd Fentress – Landstown 230 kV
Two Cedar Creek – Conastone 500 kV
Joshua Falls – Belmont 765 kV
2nd Red Lion – Keeney 500 kV
2nd Pontiac – Loretto 345 kV
2nd Loretto – Wilton Center 345 kV
2nd Peachbottom 500/230 kV
Transmission Overlay Due to Congestion
3rd Linwood – Chichester 230 kV
3rd Seward 230/115 kV
2nd Lee County – Byron 345 kV
LaSalle – Wilton Center 765 kV
2nd Yadkin – Suffolk 500 kV
Replace Fentress 500/230 kV
2nd Benton – Cook 345 kV
Reconductor Keeney – Harmony 230 kV
Reconductor Seward – Johnstown 230 kV

1.7.4 Transmission Overlay Results for 30% HSBO Scenario

The 30% HSBO scenario resulted in $8 billion of transmission upgrades, the majority ($7 billion) of which was needed to accommodate 41 GW of renewable projects in Illinois and Indiana. The transmission constraints driving the transmission overlay for the 30% HSBO scenario are shown in Table 1-20 and the transmission overlay to resolve the constraints is shown in Table 1-21.

Table 1-20: Transmission Constraints for 30% HSBO Scenario

Plano – Collins 765 kV
Collins – Wilton Center 765 kV
Wilton Center – Dumont 765 kV
Marysville – Kammer 765 kV
Mountaineer – Belmont 765 kV
Dresden – Elwood 345 kV
Pontiac – Dresden 345 kV
Pontiac – Wilton Center 345 kV
E. Frankfort – Crete 345 kV
Stillwell – Dumont 345 kV
Munster – Burnham 345 kV
Many 345 kV circuit in AEP
Many 345 kV circuits in ComEd
Quad – Sub 91 345 kV
Kanawha River – Matt Funk 345 kV
Fentress – Thrasher 230 kV
Quad Cities – Rock Creek 345 kV
Possum 500/230 kV
Electric Jct. - Lombard 345 kV

Table 1-21: Transmission Overlay for 30% HSBO Scenario

Transmission Overlay Due to Reliability
Quad Cities – La Salle 765 kV
La Salle – Pontiac 765 kV
Pontiac – Greentown 765 kV
Two Greentown – Vassell 765 kV
New Vassell – Star 765 kV
New Pontiac – Sullivan 765 kV
New Star – S. Canton 765 kV
Transmission Overlay Due to Congestion
2nd Quad – Sub 91 345 kV
Reconductor Kanawha R. – M. Funk 345 kV
2nd Fentress – Thrasher 230 kV
2nd Quad Cities – Rock Creek 345 kV
2nd Possum 500/230 kV
2nd Electric Jct. - Lombard 345 kV

1.8 Transmission Overlay Appendices

1.8.1 Appendix A: Geographic Maps for 20% Scenarios

Figure 1-8 below is a legend for the 20% scenario geographical maps shown in Appendix A.

Constraints

230 kV Overlay

345 kV Overlay

500 kV Overlay

765 kV Overlay

Figure 1-8: Legend for Geographical Maps

Transmission Constraints and Overlays for 20% LOBO Scenario

The transmission constraints and transmission overlays for the 20% LOBO scenario are listed in Table 1-22 and Table 1-23. Figure 1-9 through Figure 1-12 show the constraints and overlays geographically.

Table 1-22: Transmission Constraints for 20% LOBO

Dresden – Elwood 345 kV
Brokaw - Pontiac 345 kV
Quad - Sub 91 345 kV
Plano 765/345 kV
Quad - Rock Cities 345 kV
Kanawha River – Matt Funk 345 kV
E. Frankfort – Crete 345 kV

Table 1-23: Transmission Overlay for 20% LOBO

Transmission Overlay Due to Reliability
2nd Dresden – Elwood 345 kV
2nd Brokaw - Pontiac 345 kV
Transmission Overlay Due to Congestion
2nd Quad - Sub 91 345 kV
2nd Quad - Rock Cities 345 kV
Reconductor Kanawha R. – M. Funk 345 kV
2nd E. Frankfort – Crete 345 kV
New Plano 765/345 kV

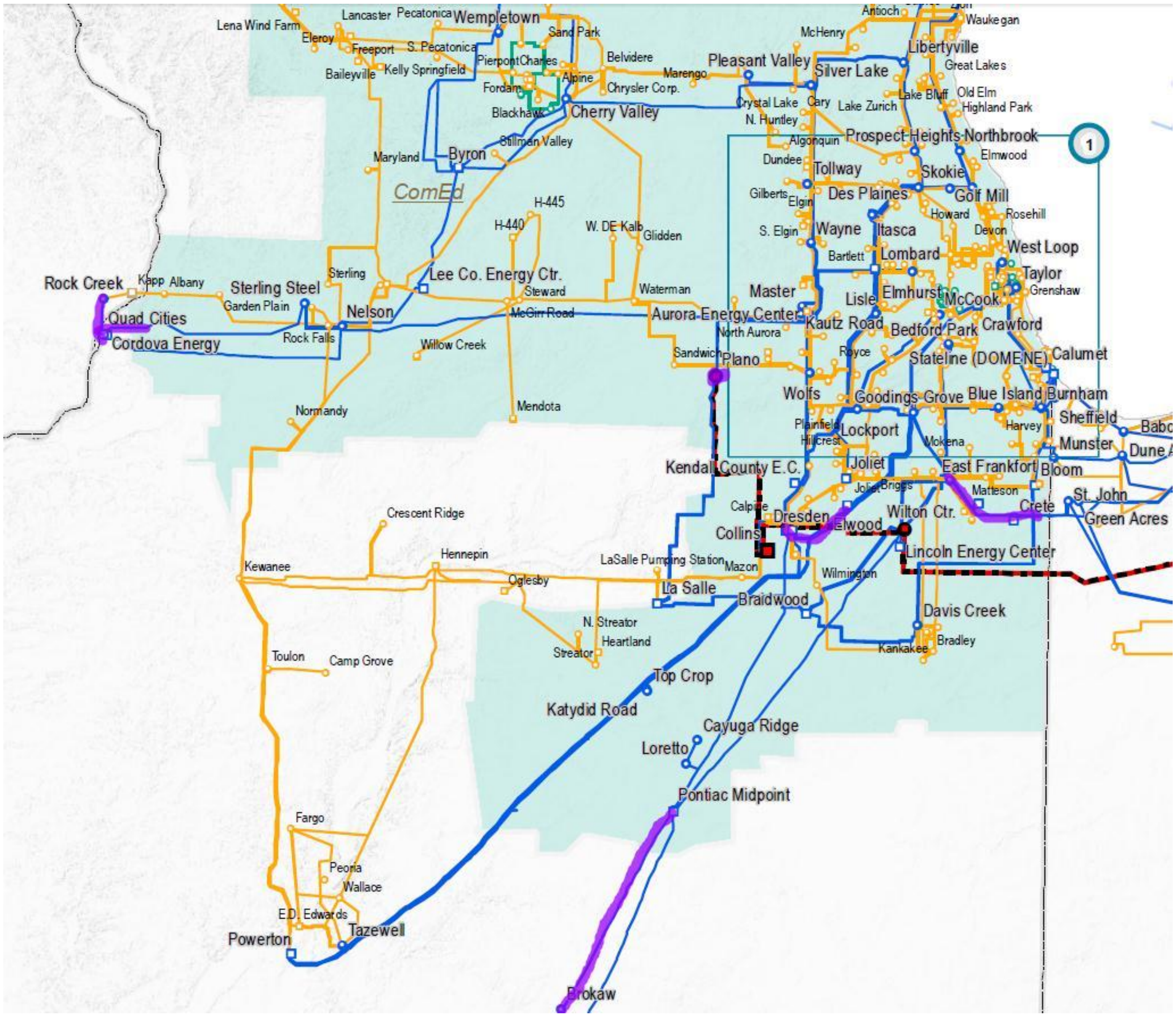

Figure 1-9: 20% LOBO Transmission Constraints – ComEd

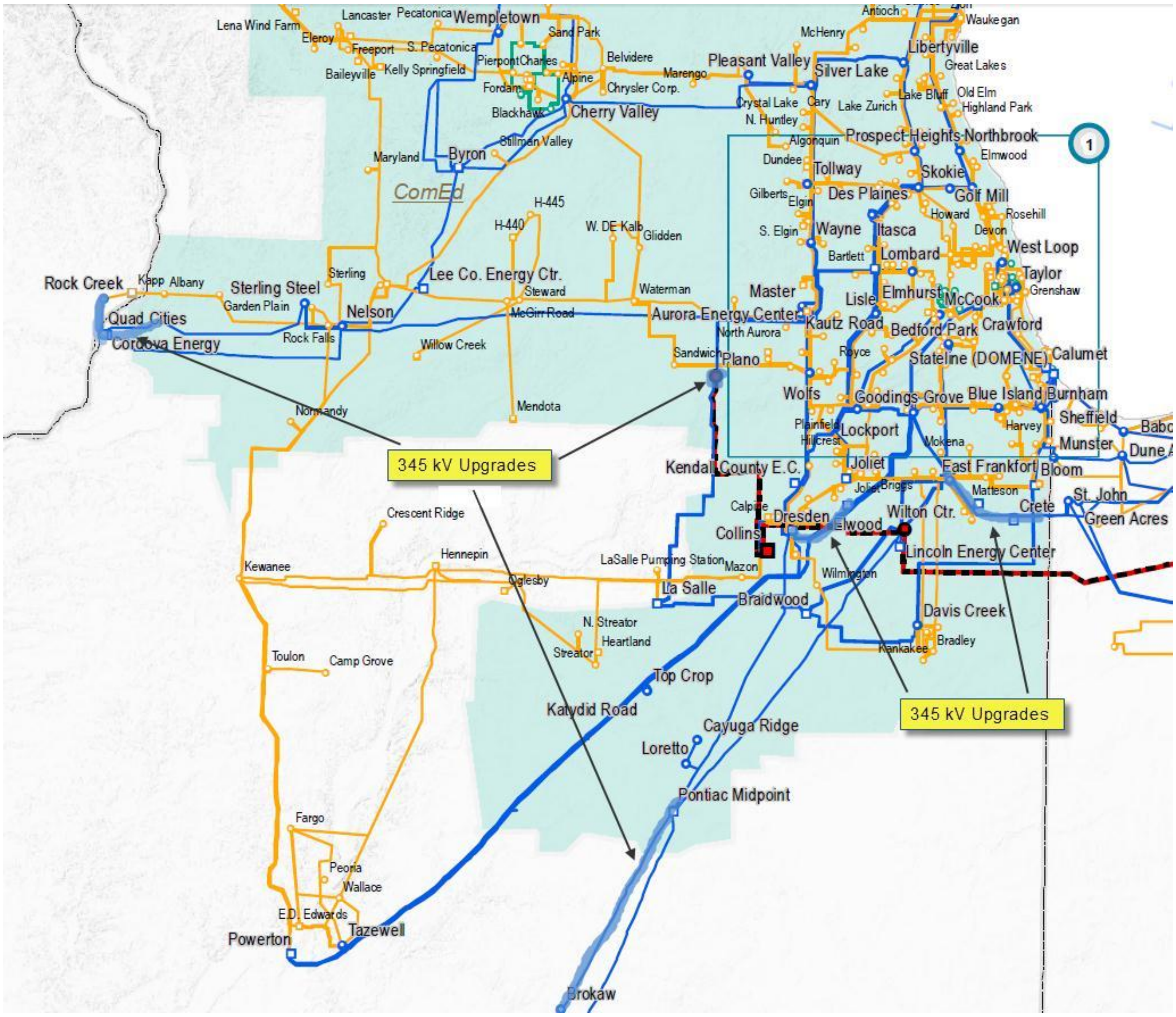

Figure 1-10: 20% LOBO Transmission Overlay – ComEd

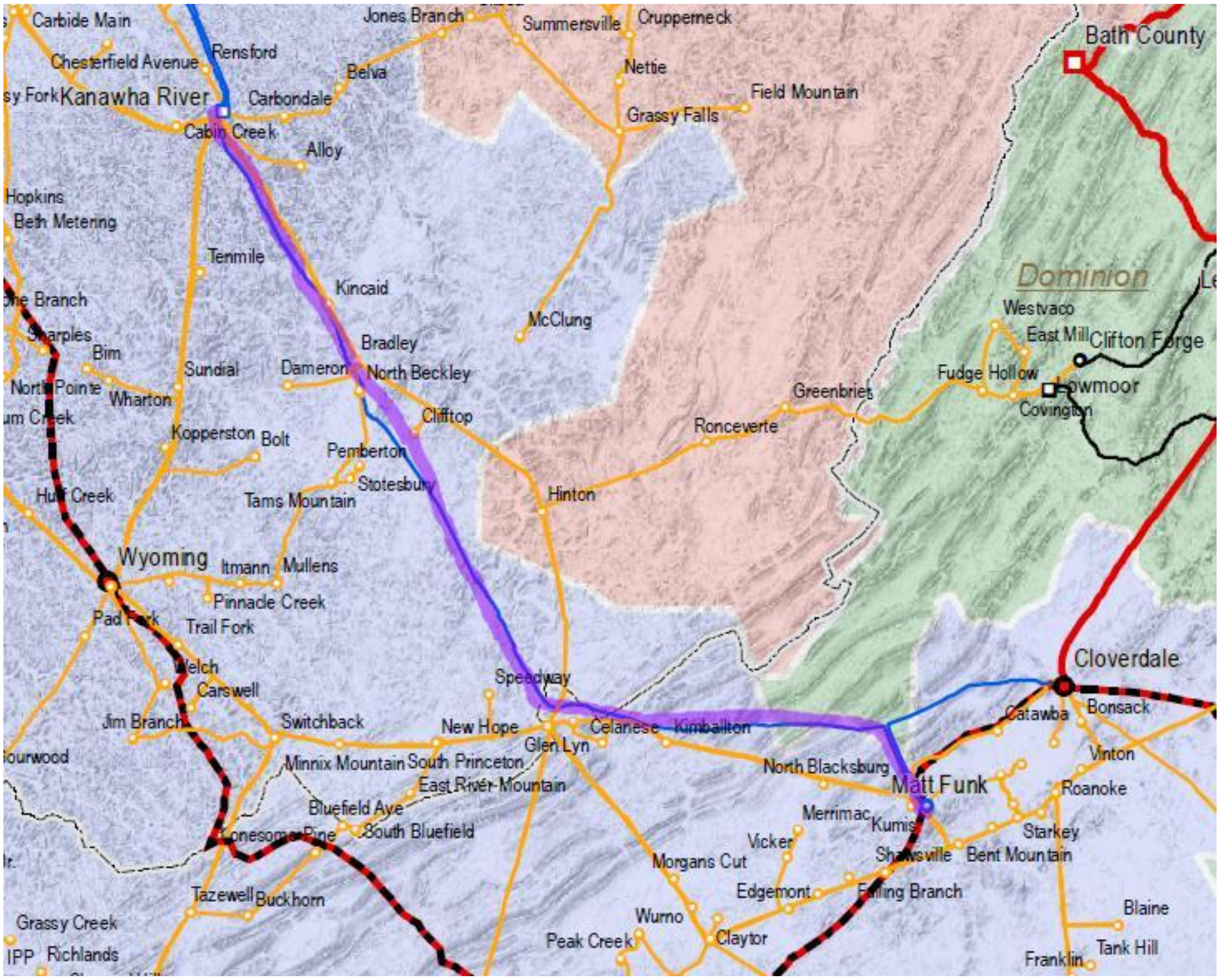

Figure 1-11: 20% LOBO Transmission Constraints – AEP

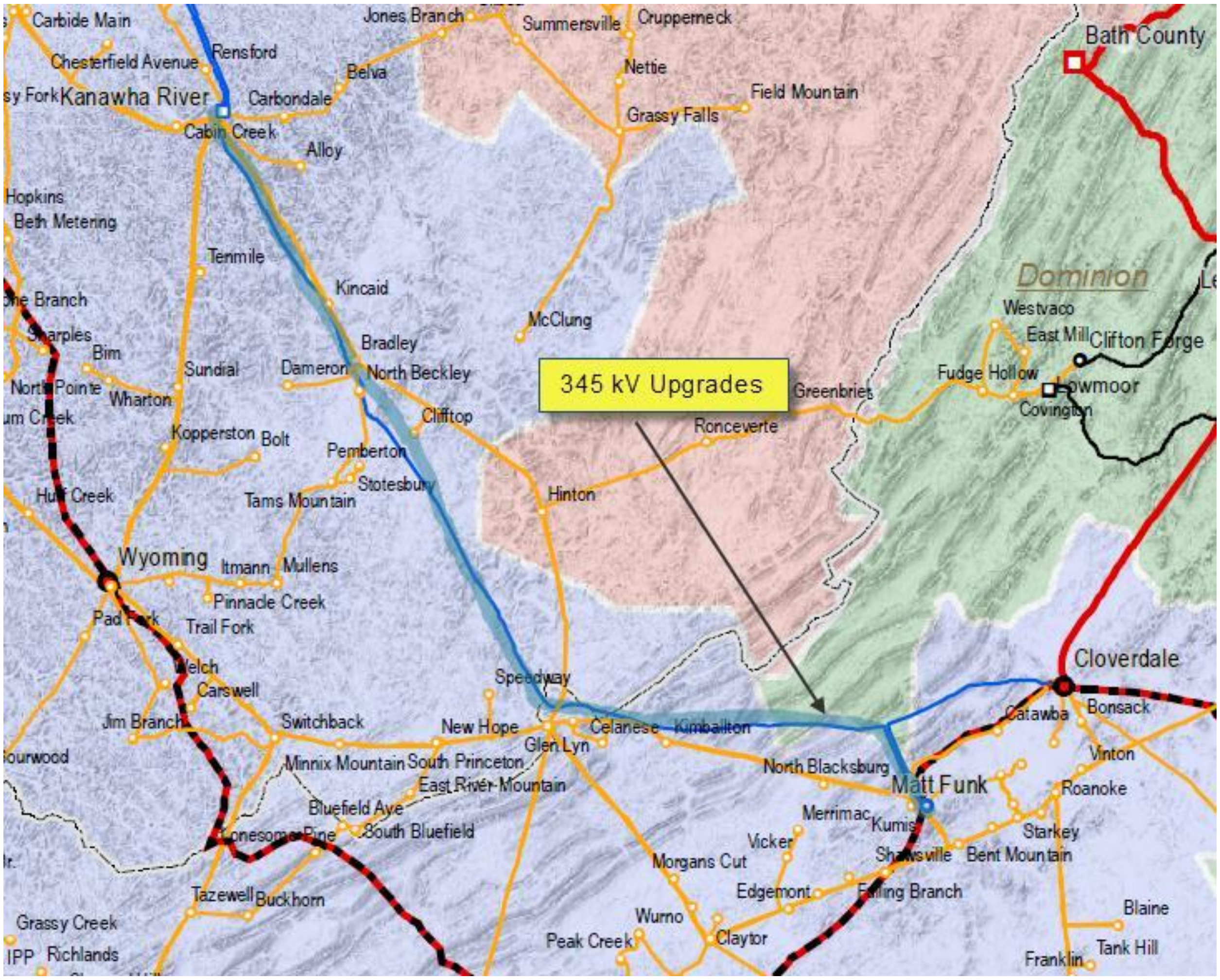

Figure 1-12: 20% LOBO Transmission Overlay – AEP

Transmission Constraints and Overlays for 20% LODO Scenario

The transmission constraints and transmission overlays for the 20% LODO scenario are listed in Table 1-24 and Table 1-25. Figure 1-13 through Figure 1-16 show the constraints and overlays geographically.

Table 1-24: Transmission Constraints for 20% LODO Scenario

Byron - Cherry Valley 345 kV
Valley 500/230 kV
Altoona – Raystown 230 kV
Raystown – Lewistown 230 kV

Table 1-25: Transmission Overlay for 20% LODO Scenario

Transmission Overlay Due to Congestion
2nd Byron - Cherry Valley 345 kV
Replace Valley 500/230 kV
Reconductor Altoona – Raystown 230 kV
Reconductor Raystown – Lewistown 230 kV

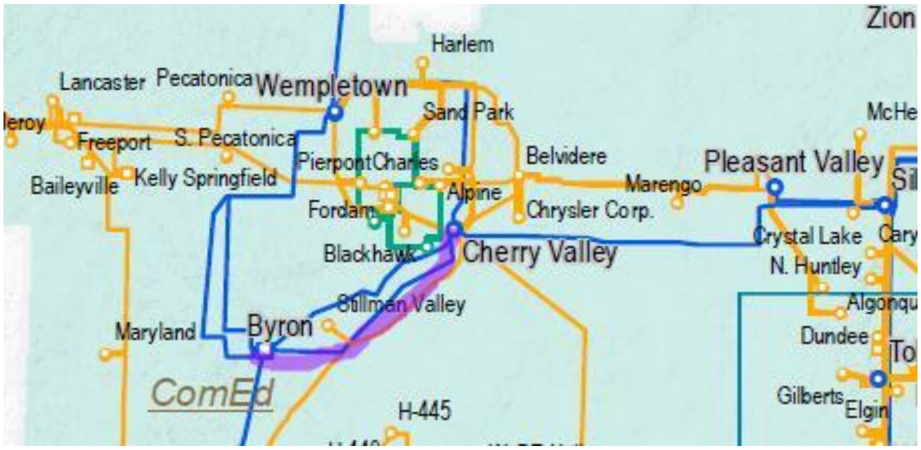

Figure 1-13: 20% LODO Transmission Constraints – ComEd

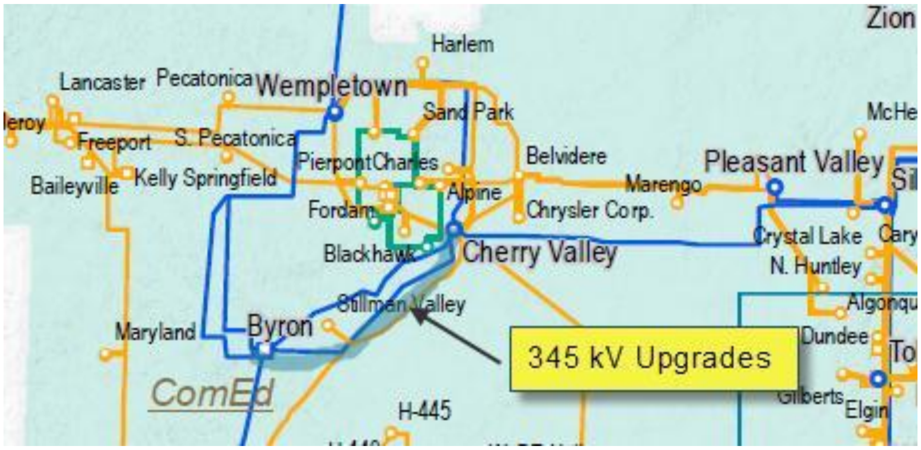

Figure 1-14: 20% LODO Transmission Overlay – ComEd

Figure 1-15: 20% LODO Transmission Constraints – Penelec

Figure 1-16: 20% LODO Transmission Overlay – Penelec

Transmission Constraints and Overlays for 20% HOBO Scenario

The transmission constraints and transmission overlays for the 20% HOBO scenario are listed in Table 1-26 and Table 1-27. Figure 1-17 through Figure 1-22 show the constraints and overlays geographically.

Table 1-26: Transmission Constraints for 20% HOBO Scenario

Fentress – Thrasher 230 kV
Fentress – Landstown 230 kV
Fentress 500/230 kV
Thrasher - Huntsman 230 kV
Huntsman - Yadkin 230 kV
Shawboro - Eliz CT 230 kV
TMI 500/230 kV
Everetts - Greenville 230 kV
Quad - Sub 91 345 kV
Kanawha River – Matt Funk 345 kV
Plano 765/345 kV

Table 1-27: Transmission Overlay for 20% HOBO Scenario

Transmission Overlay Due to Reliability
2nd Fentress – Thrasher 230 kV
2nd Fentress – Landstown 230 kV
Replace Fentress 500/230 kV
New Fentress - Carson 500 kV
2nd TMI 500/230 kV
Transmission Overlay Due to Congestion
2nd Everetts – Greenville 230 kV
2nd Quad - Sub 91 345 kV
Reconductor Kanawha R. – M. Funk 345 kV
New Plano 765/345 kV

Figure 1-17: 20% HOBO Transmission Constraints – Dominion

Figure 1-18: 20% HOBO Transmission Overlay – Dominion

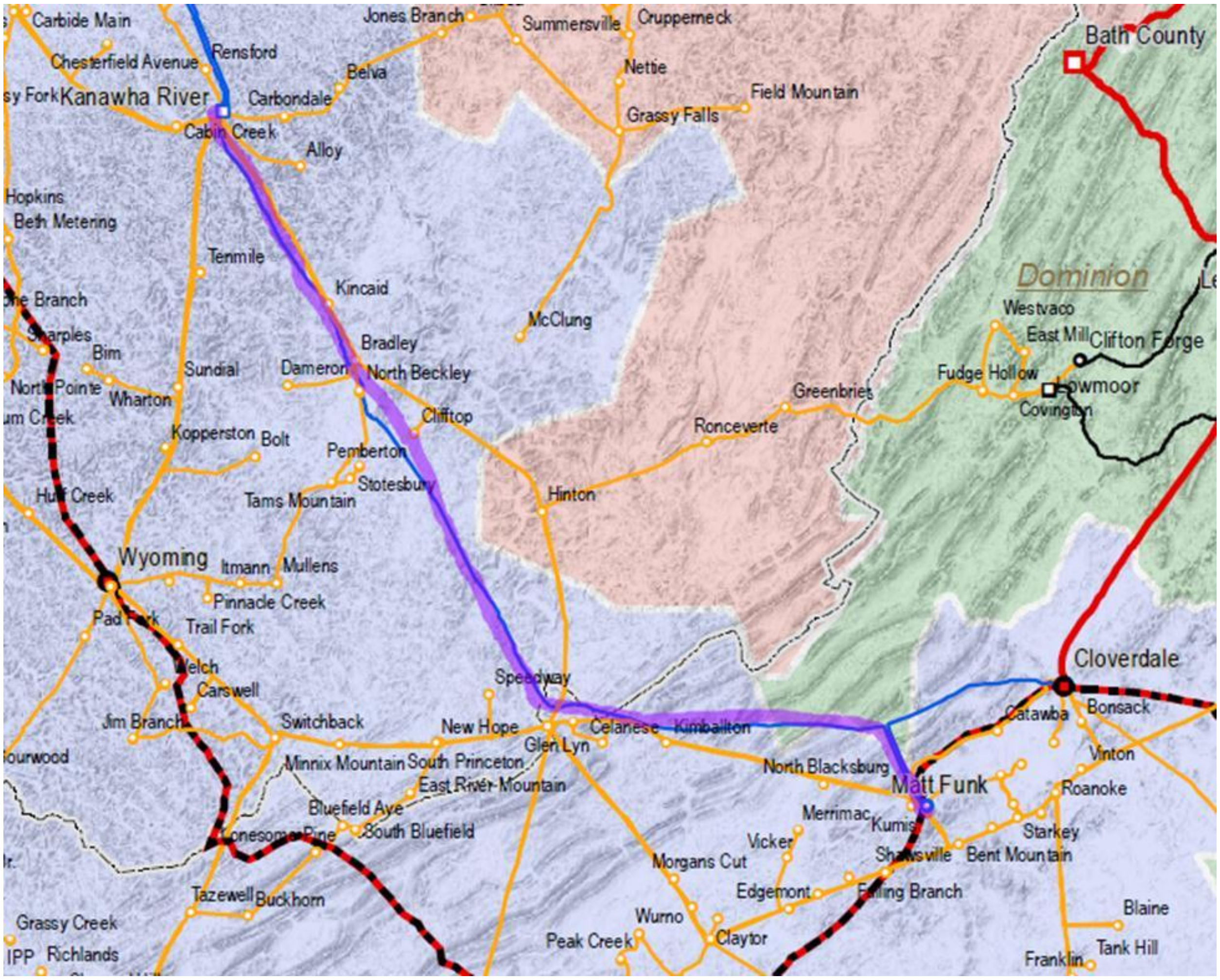

Figure 1-19: 20% HOBO Transmission Constraints – AEP

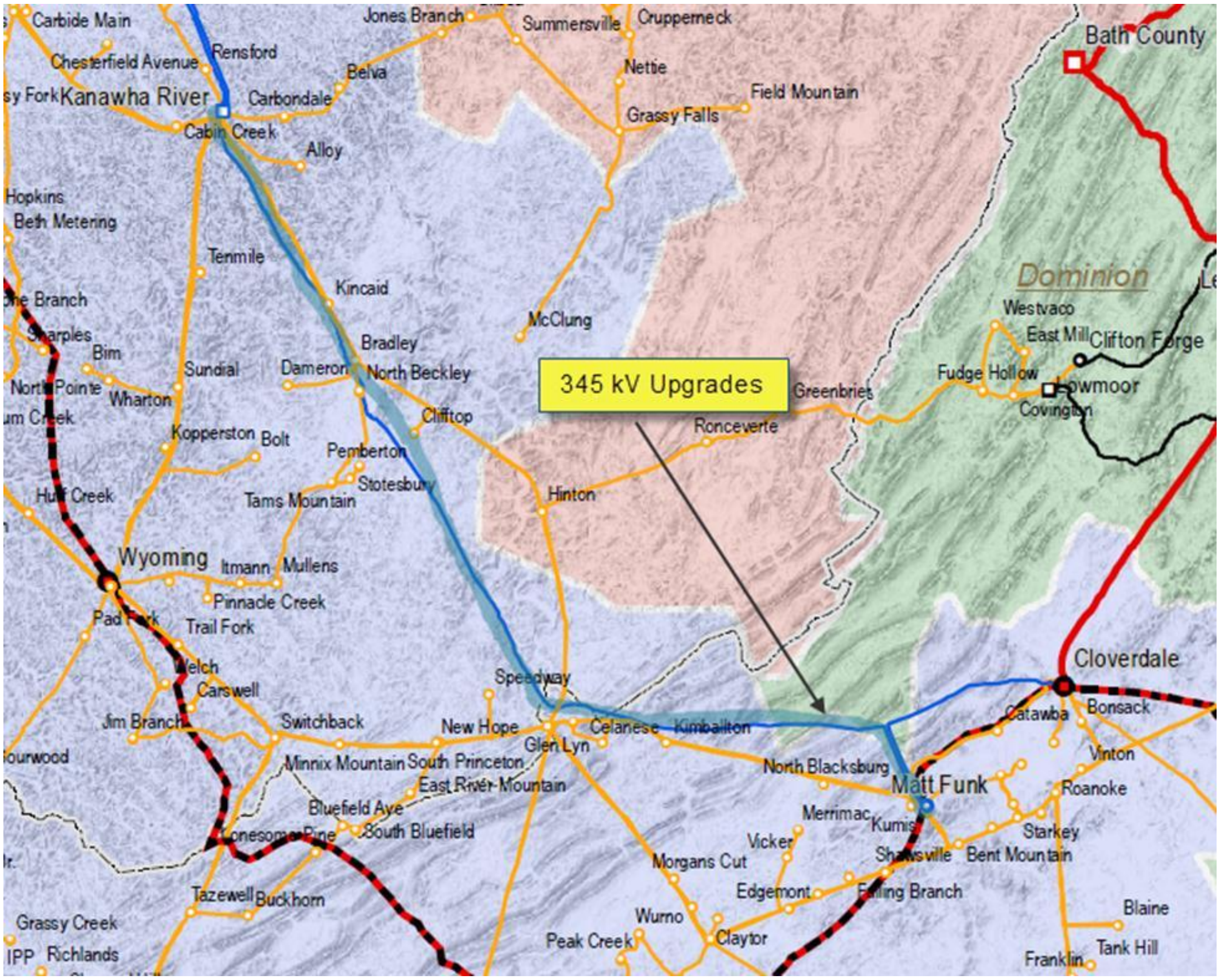

Figure 1-20: 20% HOBO Transmission Overlay – AEP

Figure 1-21: 20% HOBO Transmission Constraints – ComEd

Figure 1-22: 20% HOBO Transmission Overlay – ComEd

Transmission Constraints and Overlays for 20% HSBO Scenario

The transmission constraints and transmission overlays for the 20% High Solar Best Onshore scenario are listed in Table 1-28 and Table 1-29. Figure 1-23 through Figure 1-26 show the constraints and overlays geographically.

Table 1-28: Transmission Constraints for 20% HSBO Scenario

Plano 765/345 kV
Kanawha River – Matt Funk 345 kV
E. Frankfort – Crete 345 kV

Table 1-29: Transmission Overlay for 20% HSBO Scenario

Transmission Overlay Due to Congestion
New Plano 765/345 kV
Reconductor Kanawha R. – M. Funk 345 kV
2nd E. Frankfort – Crete 345 kV

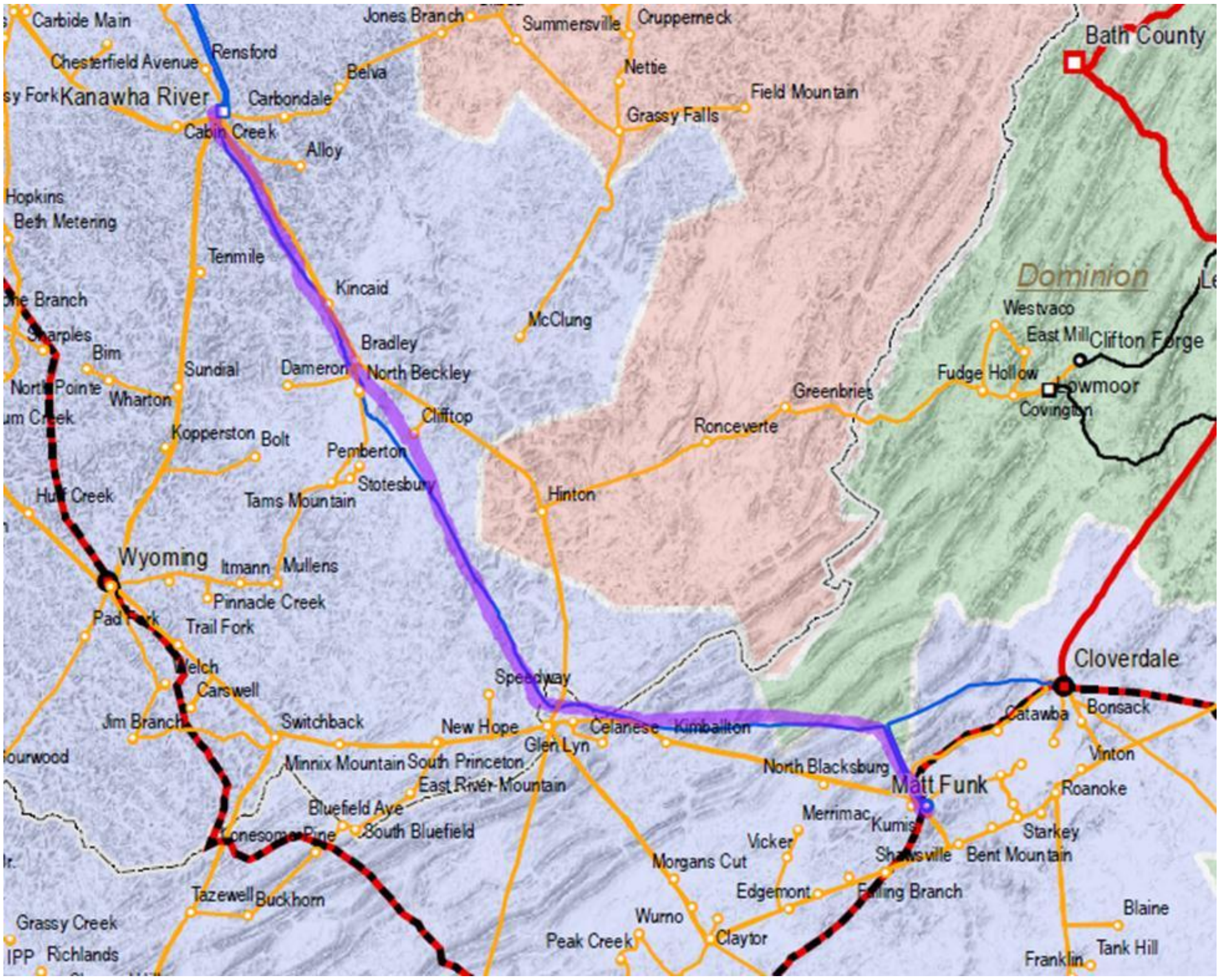

Figure 1-23: 20% HSBO Transmission Constraints – AEP

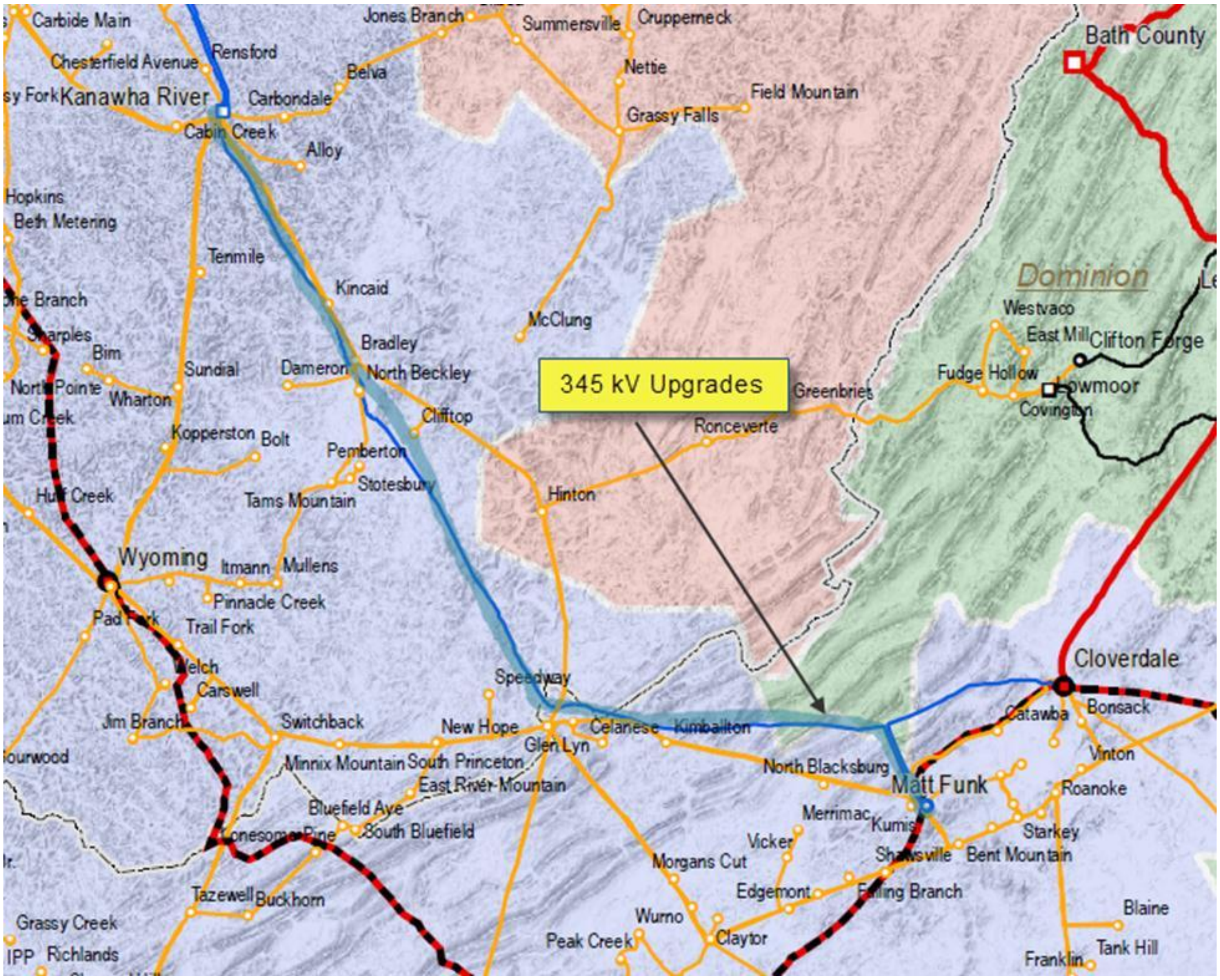

Figure 1-24: 20% HSBO Transmission Overlay – AEP

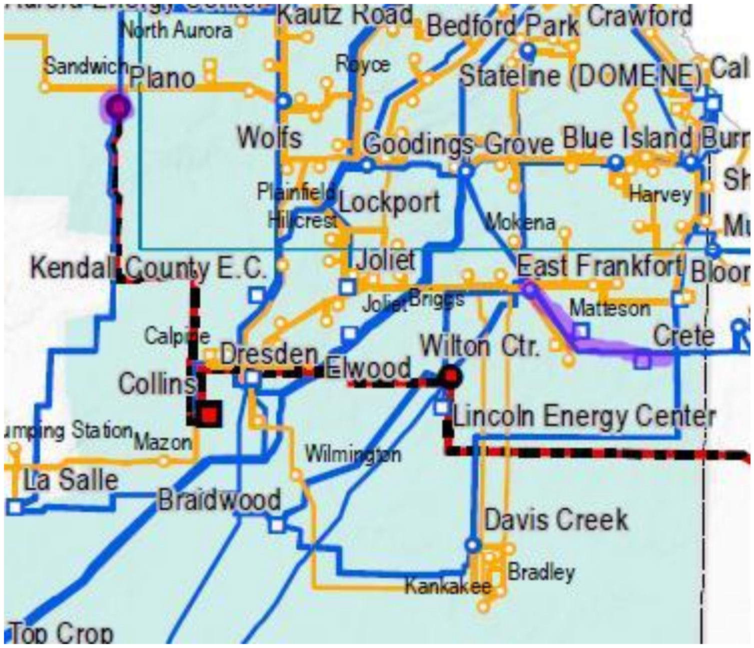

Figure 1-25: 20% HSBO Transmission Constraints – ComEd

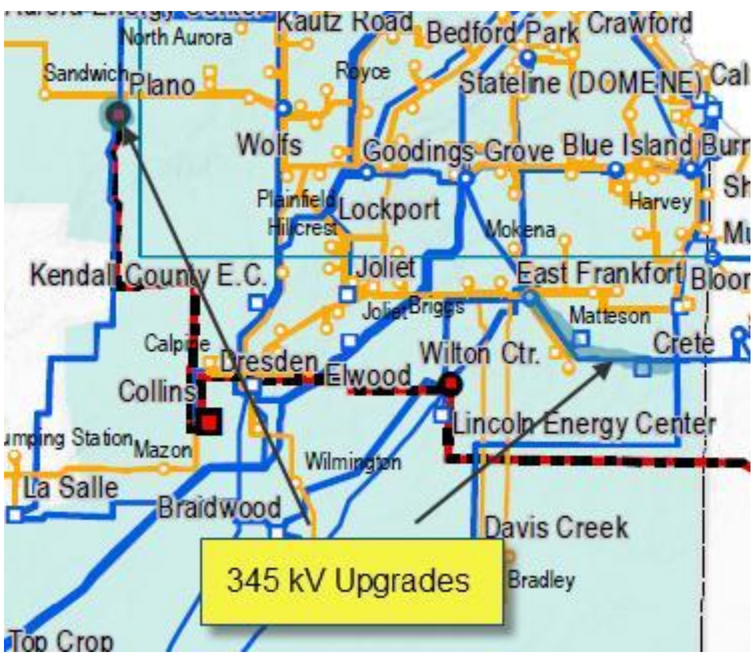

Figure 1-26: 20% HSBO Transmission Overlay – ComEd

1.8.2 Appendix B: Geographic Maps for 30% Scenarios

Figure 1-27 below is a legend for the 30% scenario geographical maps shown in Appendix B1.

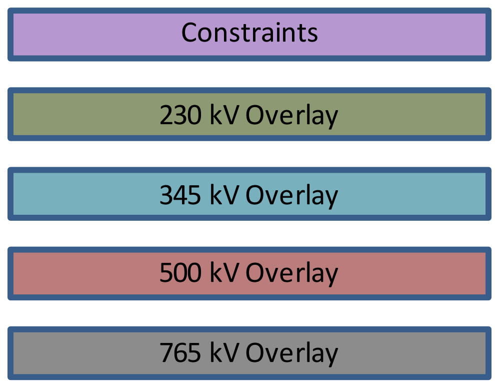

Figure 1-27: Legend for Geographical Maps

Transmission Constraints and Overlays for 30% LOBO Scenario

The transmission constraints and transmission overlays for the 30% LOBO scenario are listed in Table 1-30 and Table 1-31. Figure 1-28 through Figure 1-35 show the constraints and overlays geographically.

Table 1-30: Transmission Constraints for 30% LOBO Scenario

Plano – Collins 765 kV	Conastone - Emory Grove 230 kV
Collins – Wilton Center 765 kV	Glade - Warren 230 kV
Wilton Center – Dumont 765 kV	Seward - Johnstown 230 kV
Marysville – Kammer 765 kV	Seward 230/115 kV
Mountaineer – Belmont 765 kV	Homer City 345/230 kV
Dresden – Elwood 345 kV	Watercure - Homer City 345 kV
Pontiac – Dresden 345 kV	Pontiac 765/345 kV
Pontiac – Wilton Center 345 kV	La Salle 765/345 kV
Lee County – Nelson 345 kV	Breed - Casey 345 kV
Dresden – Electric Jct. 345 kV	Jefferson 765/345 kV
E. Frankfort – Crete 345 kV	Pleasant View - Ashburn 230 kV
Crete – St. John 345 kV	Kammer 765/500 kV
Reynolds – Olive 345 kV	Fentress 500/230 kV
Stillwell – Dumont 345 kV	Bayshore - Monroe 345 kV
Munster – Burnham 345 kV	Convoy - R60 345 kV
Many 345 kV circuit in AEP	Bremo - Powhatan 230 kV
Many 345 kV circuits in ComEd	Everetts - Greenville 230 kV
Quad – Sub 91 345 kV	Pleasant View 500/230 kV
Fentress – Thrasher 230 kV	Chesterfield - Tyler 230 kV
Fentress – Landstown 230 kV	Person - Halifax 230 kV
Valley 500/230 kV	Powhatan - Judes 230 kV
Kanawha River – Matt Funk 345 kV	Zion - Pleasant Prairie 345 kV
New Freedom - Monroe 230 kV	

Table 1-31: Transmission Overlay for 30% LOBO Scenario

Transmission Overlay Due to Reliability	Transmission Overlay Due to Congestion
Quad Cities – La Salle 765 kV	3rd Seward 230/115 kV
Two La Salle – Pontiac 765 kV	Replace Homer City 345/230 kV
Two Pontiac – Greentown 765 kV	2nd Watercure - Homer City 345 kV
Two Greentown – Vassell 765 kV	New Pontiac 765/345 kV
Two New Vassell – Star 765 kV	New La Salle 765/345 kV
Star – Keystone 765 kV	2nd Breed - Casey 345 kV
Star – S. Canton 765 kV	New Jefferson 765/345 kV
Pontiac – Sullivan 765 kV	Reconductor Pl. View - Ashburn 230 kV
Sullivan – Jefferson 765 kV	New Kammer 765/550 kV
Jefferson – Belmont 765 kV	Replace Fentress 500/230 kV
2nd Lee County – Nelson 345 kV	2nd Eugene - Bunsonville 345 kV
2nd Reynolds – Olive 345 kV	2nd T94A - Palisades 345 kV
2nd Quad Cities – Rock Creek 345 kV	2nd Bayshore - Monroe 345 kV
2nd Marysville – Hyatt 345 kV	2nd Olive - Dumont 345 kV
	2nd Brokaw - Pontiac 345 kV
	Reconductor Convoy - R60 345 kV
	2nd Everetts – Greenville 230 kV
	2nd Pleasant View 500/230 kV
	Reconductor Chesterfield - Tyler 230 kV
	Reconductor Person - Halifax 230 kV
	Reconductor Powhatan - Judes 230 kV
	2nd Zion - Pleasant Prairie 345 kV
	2nd Quad – Sub 91 345 kV
	2nd Fentress – Thrasher 230 kV
	2nd Fentress – Landstown 230 kV
	Replace Valley 500/230 kV
	Reconductor Kanawha R. – M. Funk 345 kV
	2nd New Freedom - Monroe 230 kV
	3rd Conastone - Emory Grove 230 kV
	Reconductor Glade - Warren 230 kV
	Reconductor Seward - Johnstown 230 kV

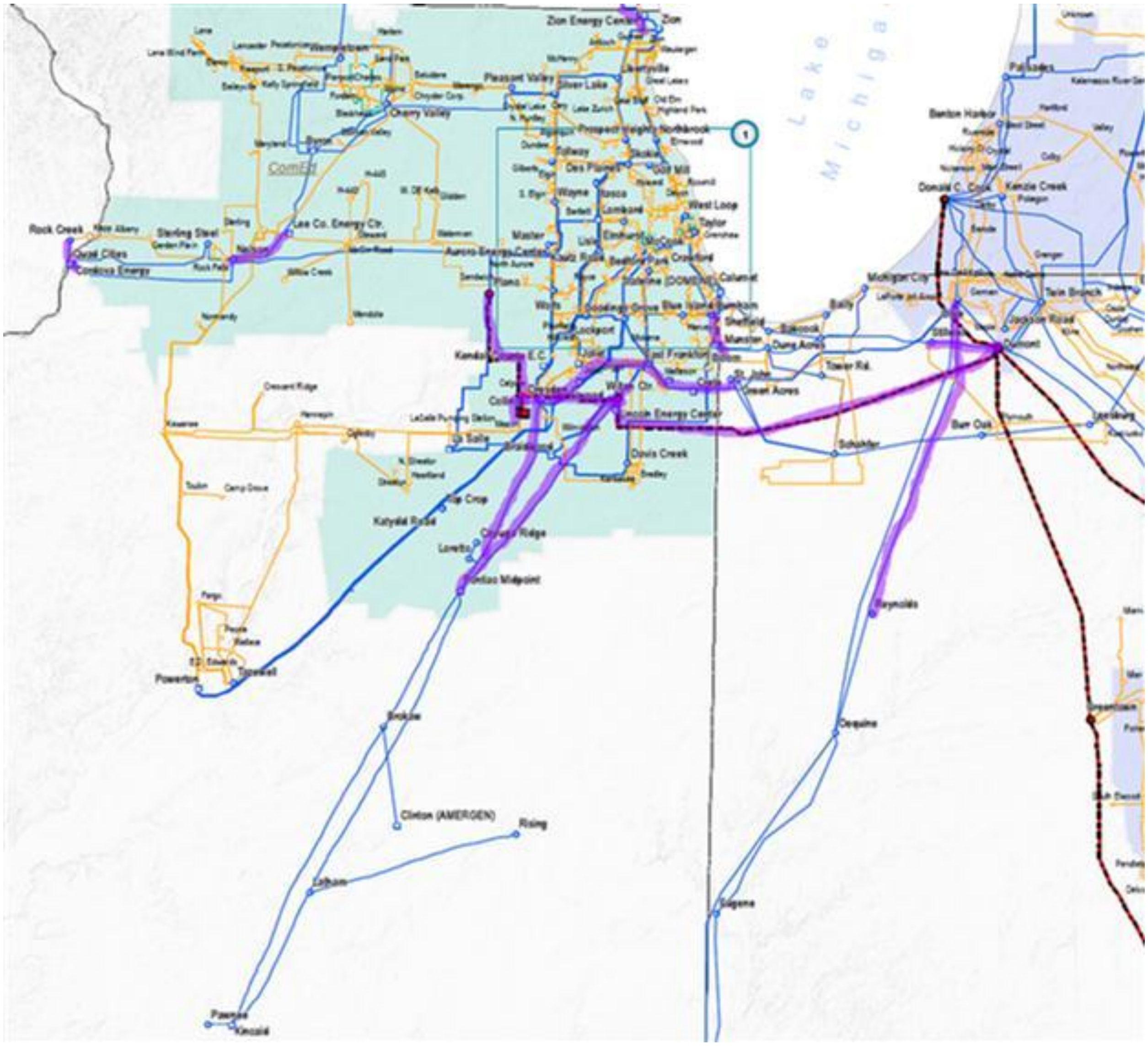

Figure 1-28: 30% LOBO Transmission Constraints – ComEd

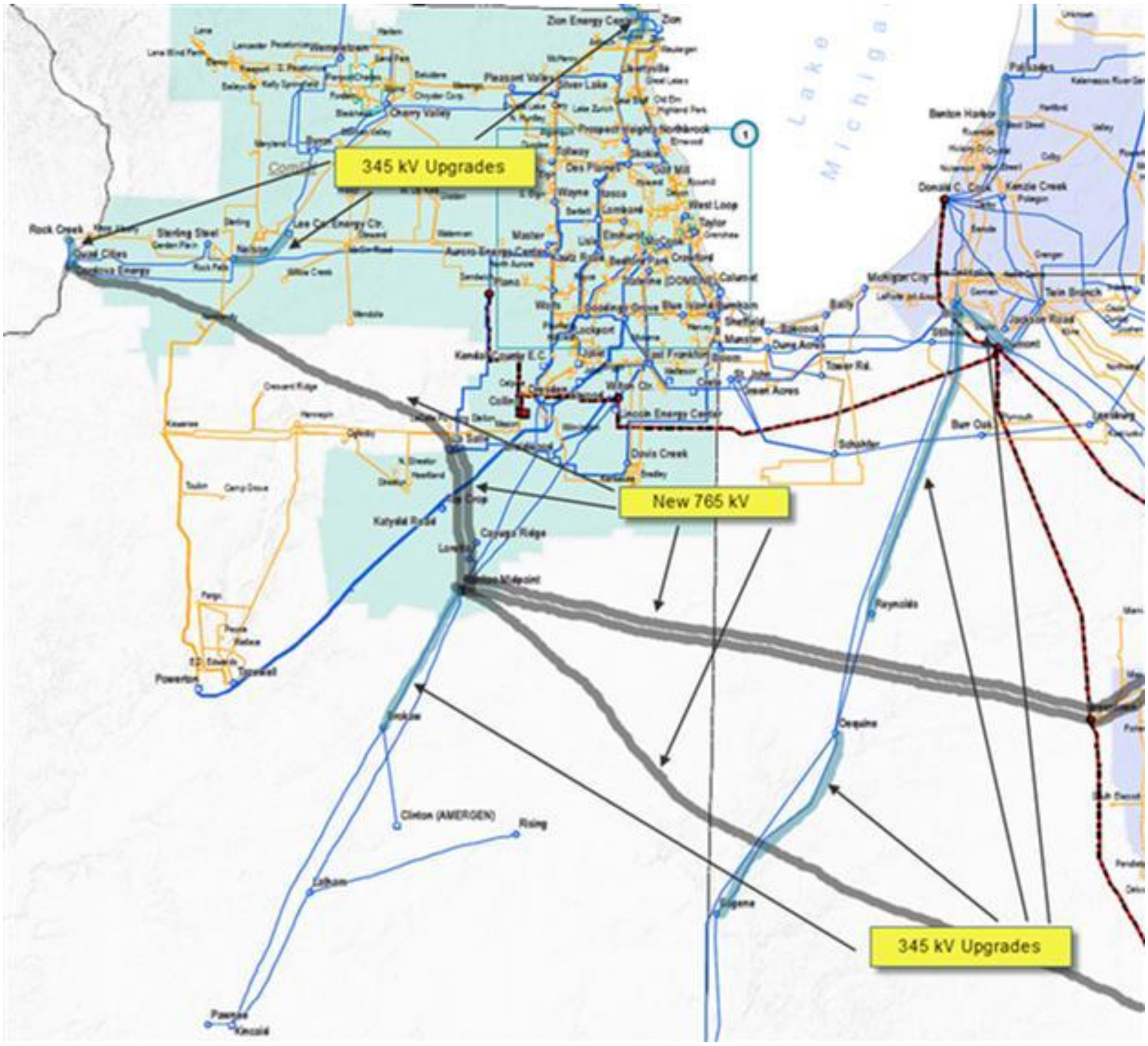

Figure 1-29: 30% LOBO Transmission Overlay – ComEd

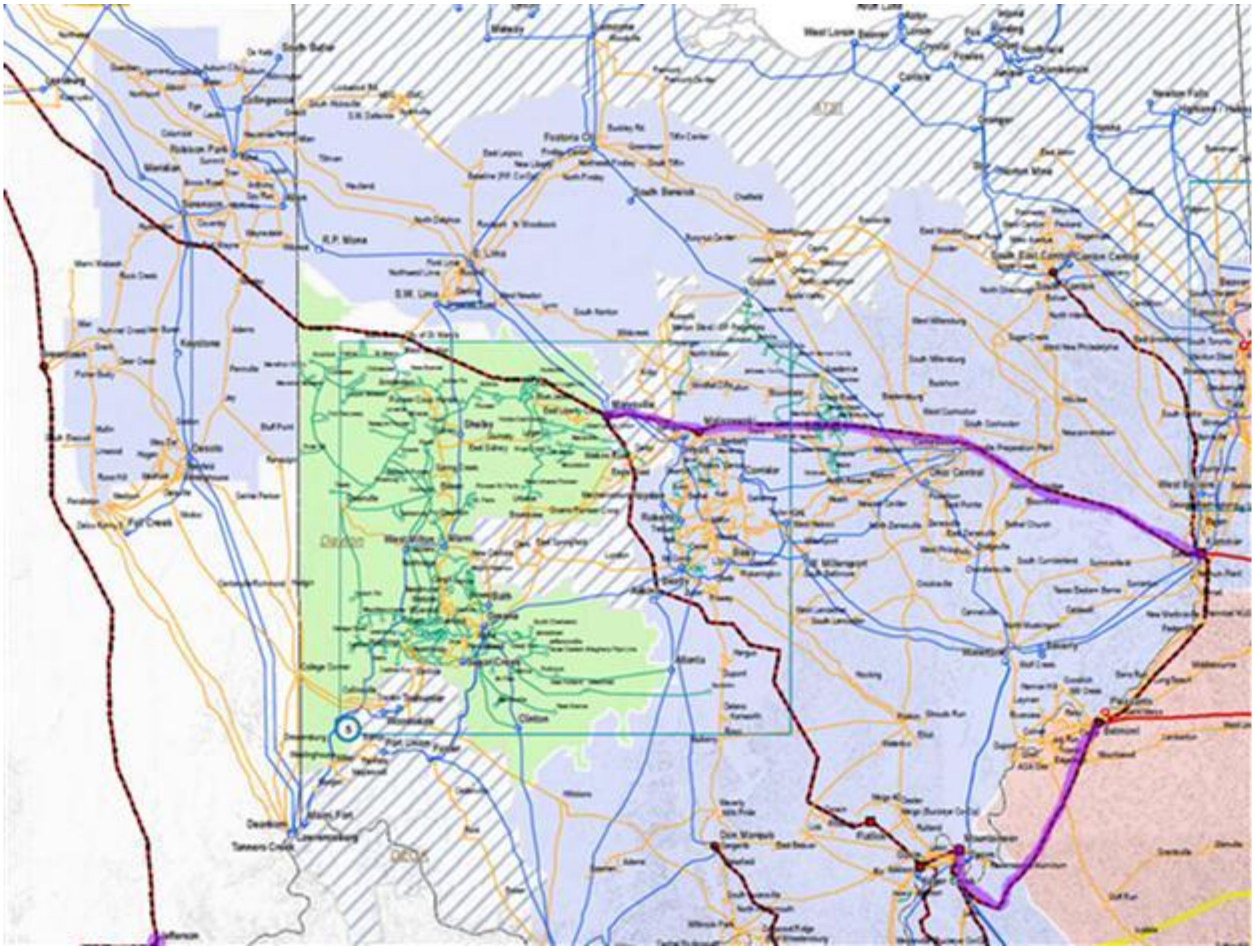

Figure 1-30: 30% LOBO Transmission Constraints – AEP

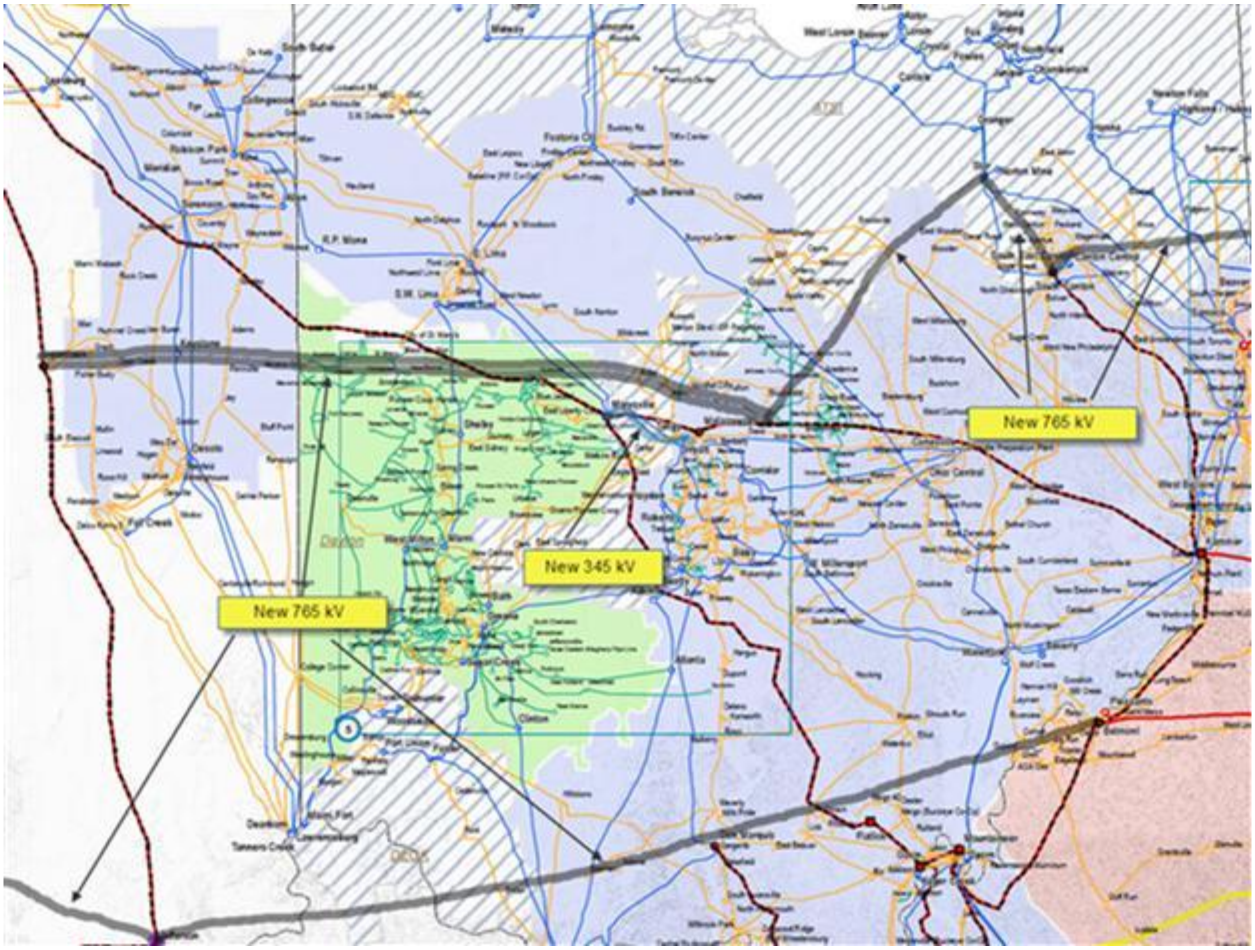

Figure 1-31: 30% LOBO Transmission Overlay – AEP

Figure 1-32: 30% LOBO Transmission Constraints – Dominion

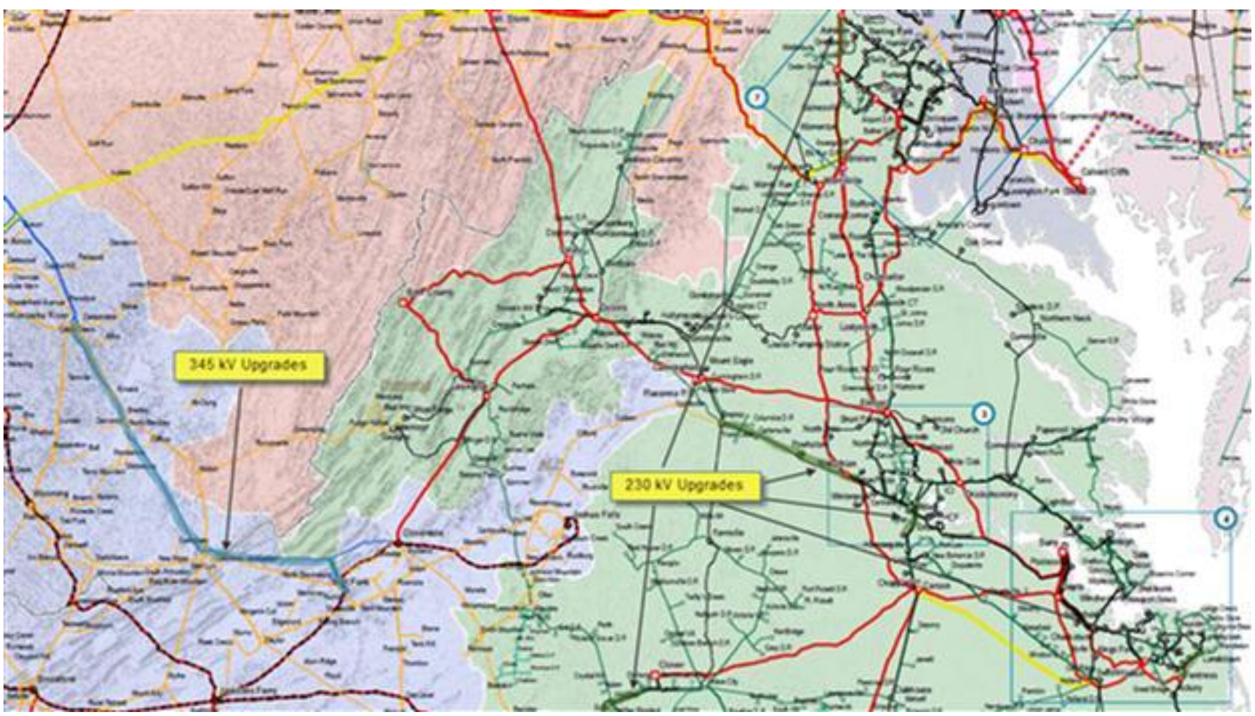

Figure 1-33: 30% LOBO Transmission Overlay – Dominion

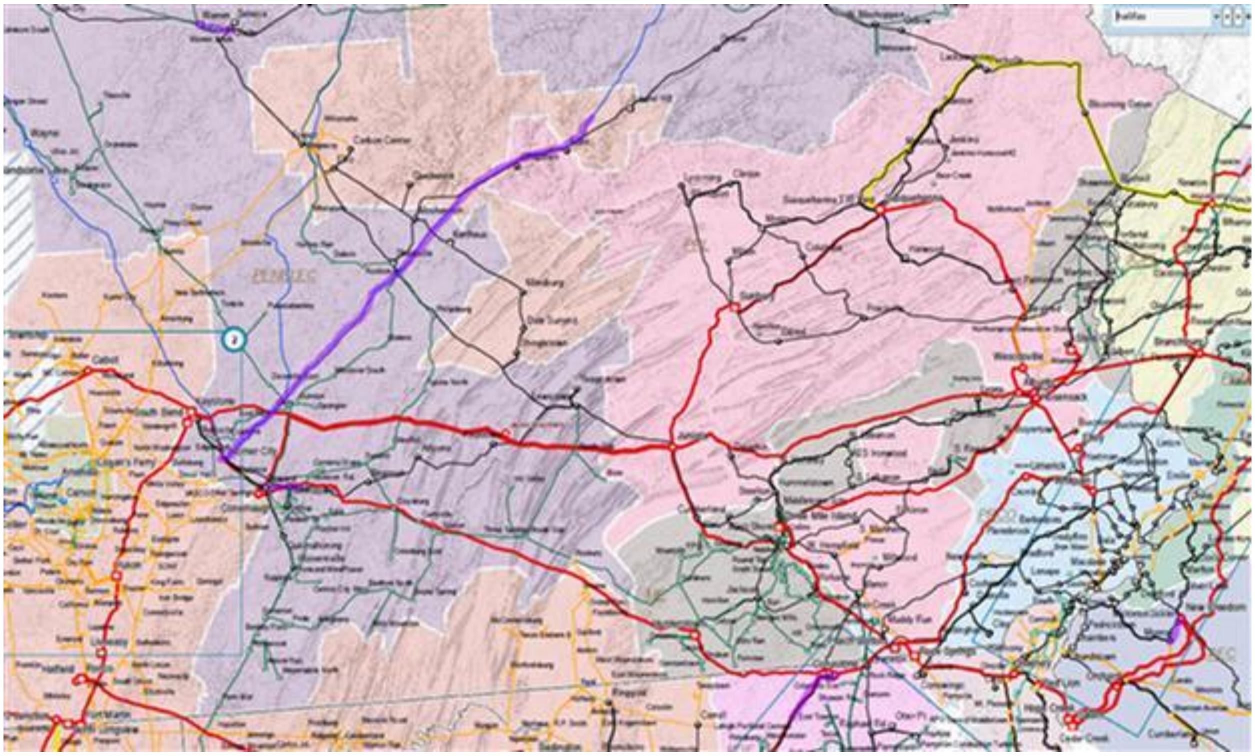

Figure 1-34: 30% LOBO Transmission Constraints – Mid-Atlantic Region

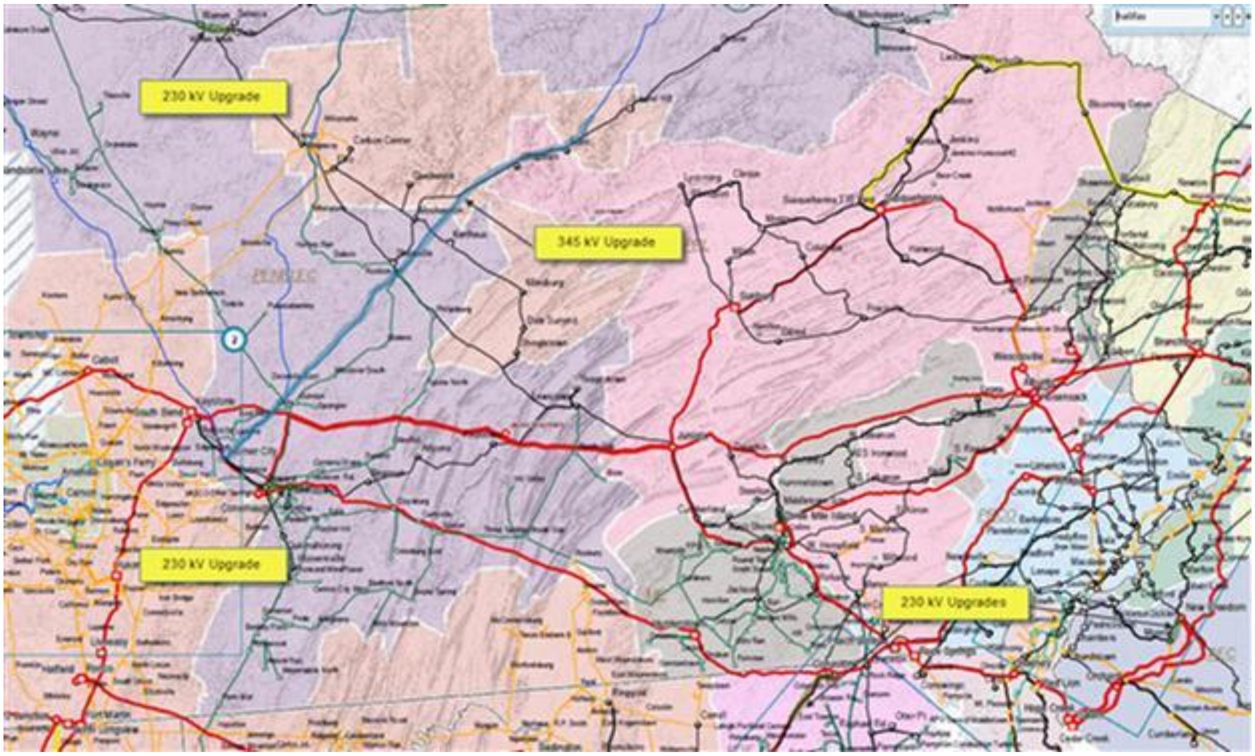

Figure 1-35: 30% LOBO Transmission Overlay – Mid-Atlantic Region

Transmission Constraints and Overlays for 30% LODO Scenario

The transmission constraints and transmission overlays for the 30% LODO scenario are listed in Table 1-32 and Table 1-33. Figure 1-36 through Figure 1-43 show the constraints and overlays geographically.

Table 1-32: Transmission Constraints for 30% LODO Scenario

Dresden – Elwood 345 kV
Pontiac – Wilton Center 345 kV
La Salle – Plano 345 kV
E. Frankfort – Braidwood 345 kV
Plano – Electric Jct. 345 kV
Marysville – Hyatt 345 kV
Pearson – Halifax 230 kV
Clover – Halifax 230 kV
Altoona – Raystown 230 kV
Raystown – Lewistown 230 kV
Quad – Sub 91 345 kV
Everetts – Greenville 230 kV
Fentress – Thrasher 230 kV
Fentress – Landstown 230 kV
Valley 500/230 kV
Kanawha River – Matt Funk 345 kV
Davis Besse – Beaver 345 kV

Table 1-33: Transmission Overlay for 30% LODO Scenario

Transmission Overlay Due to Reliability
LaSalle – Pontiac 765 kV
Two Pontiac 765/345 kV
2nd Marysville – Hyatt 345 kV
2nd Pearson – Halifax 230 kV
Pontiac – Greentown 765 kV
2nd Clover – Halifax 230 kV
Transmission Overlay Due to Congestion
Reconductor Altoona – Raystown 230 kV
Reconductor Raystown – Lewistown 230 kV
2nd Quad – Sub 91 345 kV
2nd Everetts – Greenville 230 kV
2nd Fentress – Thrasher 230 kV
2nd Fentress – Landstown 230 kV
Replace Valley 500/230 kV
Reconductor Kanawha R. – M. Funk 345 kV
Reconductor Davis Besse – Beaver 345 kV

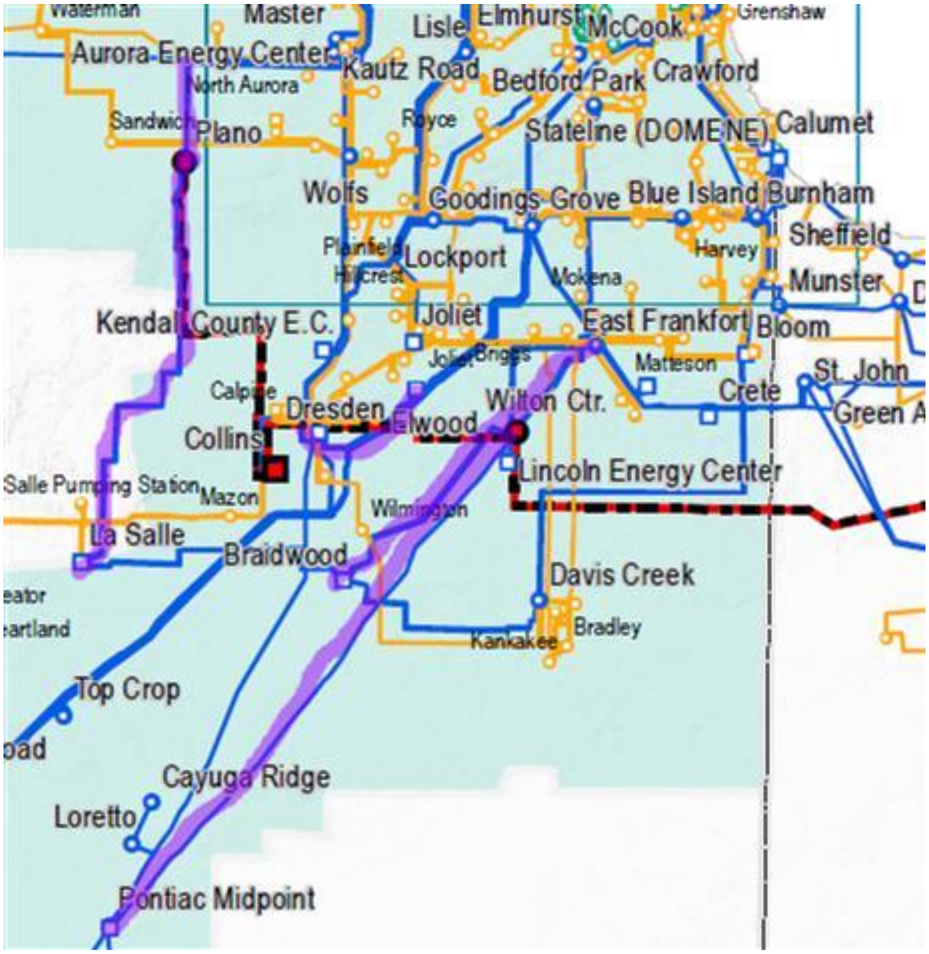

Figure 1-36: 30% LODO Transmission Constraints – ComEd

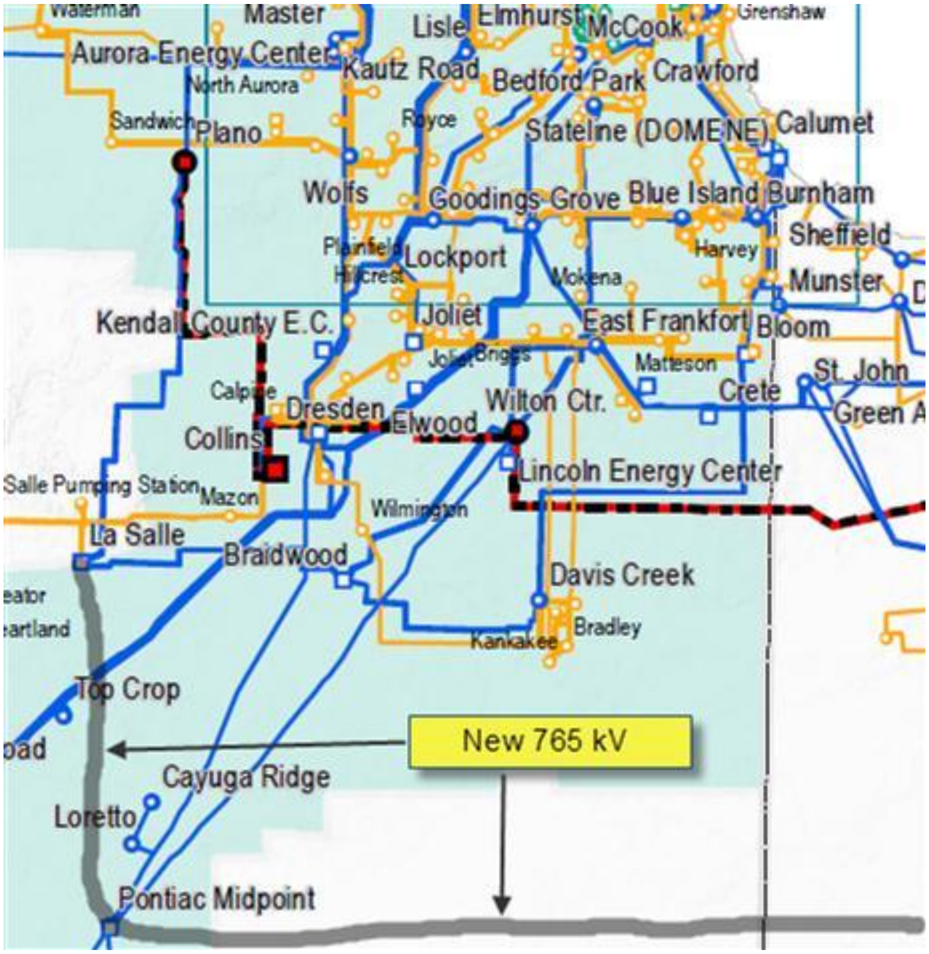

Figure 1-37: 30% LODO Transmission Overlay – ComEd

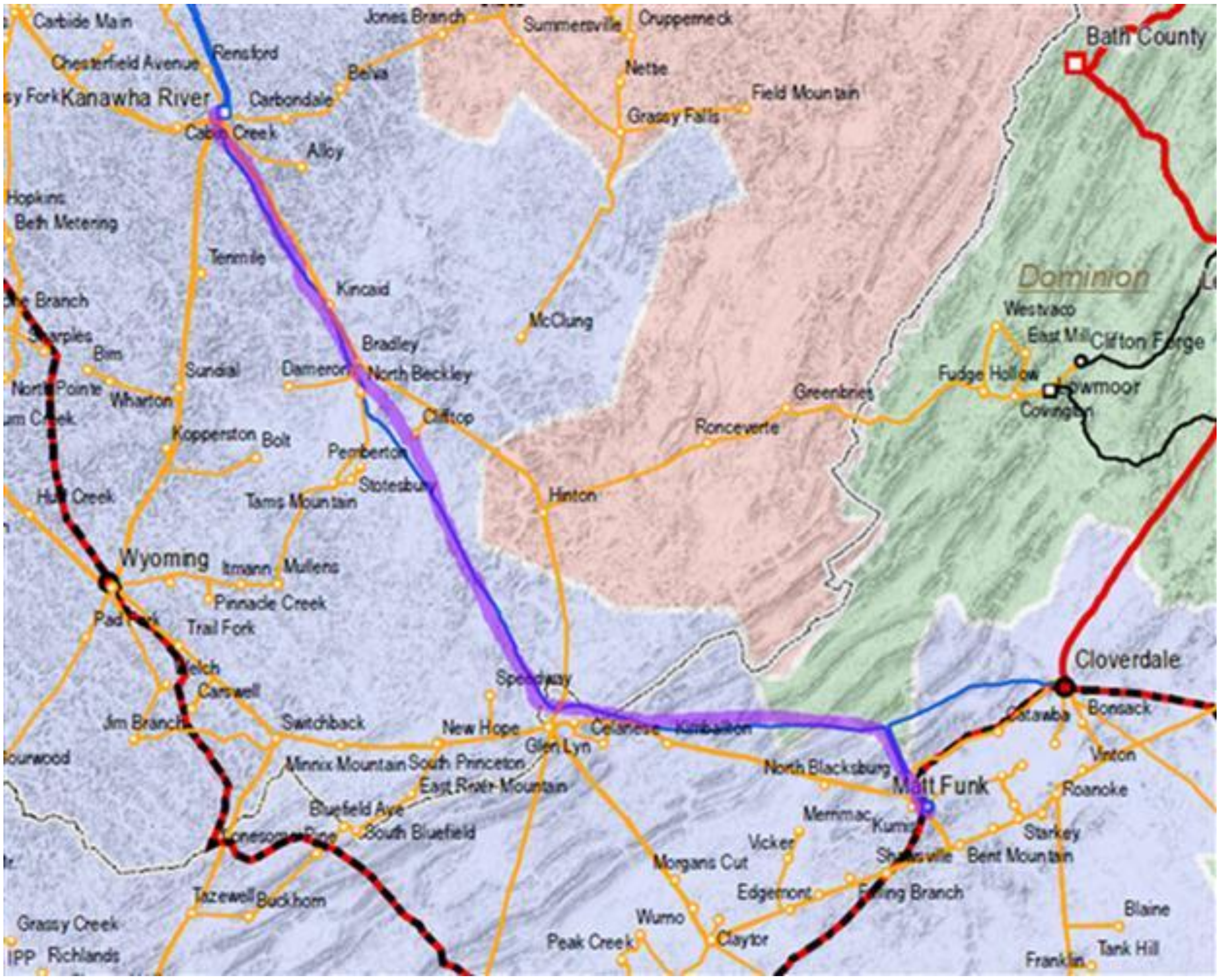

Figure 1-38: 30% LODO Transmission Constraints – AEP

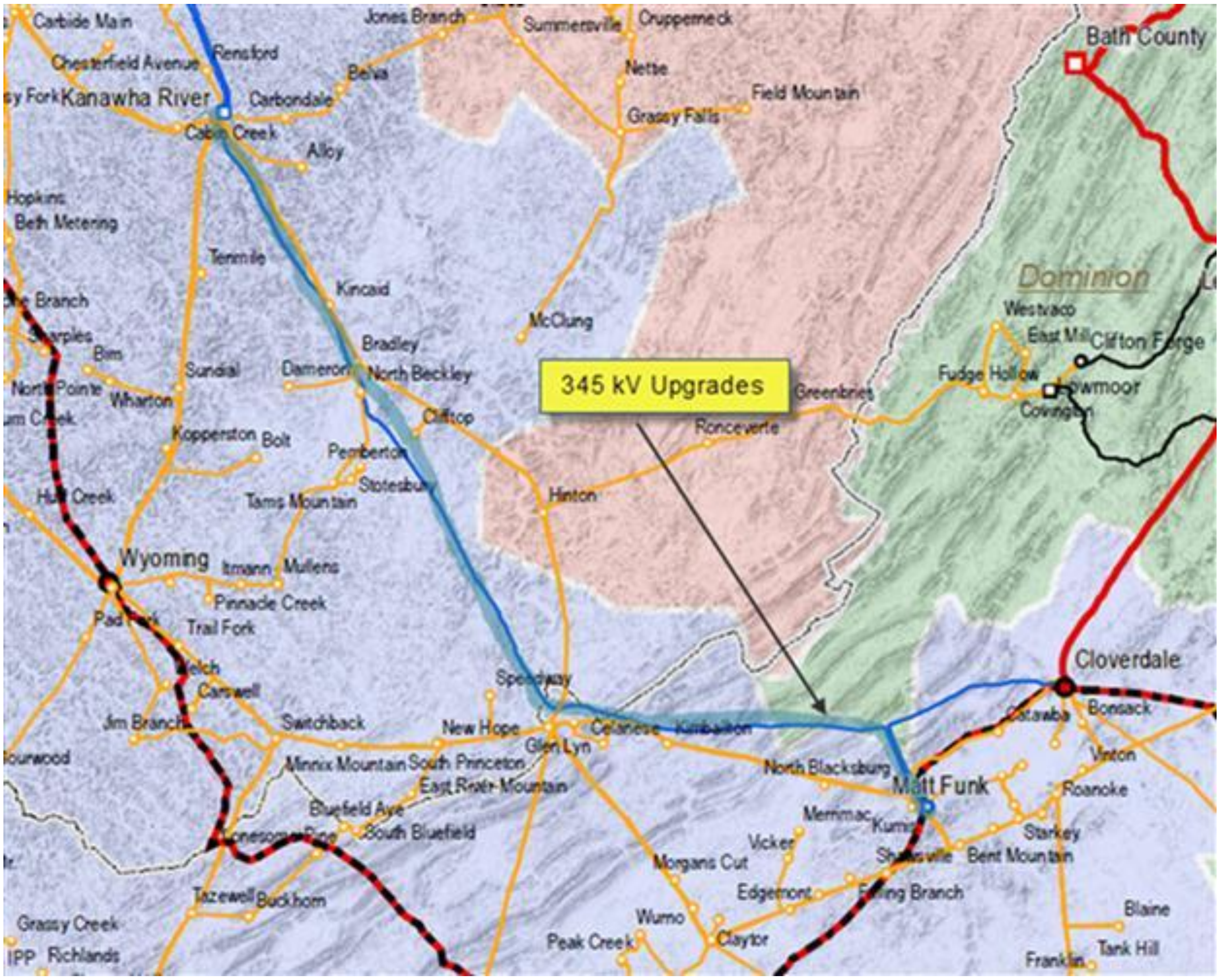

Figure 1-39: 30% LODO Transmission Overlay – AEP

Figure 1-40: 30% LODO Transmission Constraints – Dominion

Figure 1-41: 30% LODO Transmission Constraints – Dominion

Figure 1-42: 30% LODO Transmission Constraints – Penelec

Figure 1-43: 30% LODO Transmission Overlay – Penelec

Transmission Constraints and Overlays for 30% HOBO Scenario

The transmission constraints and transmission overlays for the 30% High Offshore Best Onshore scenario are listed in Table 1-34 and Table 1-35. Figure 1-44 through Figure 1-49 show the constraints and overlays geographically.

Table 1-34: Transmission Constraints for 30% HOBO Scenario

Fentress – Septa 500 kV
Septa – Surry 500 kV
Septa – Carson 500 kV
Yadkin – Suffolk 500 kV
Surry - Chickahominy 500 kV
Chickahominy – Elmont 500 kV
Elmont – Ladysmith 500 kV
Ladysmith – North Anna 500 kV
North Anna – Morrisville 500 kV
Keeney – Red Lion 500 kV
Keeney – Rock Springs 500 kV
Rock Springs – Peach Bottom 500 kV
Red Lion – Hope Creek 500 kV
Cedar Creek – Red Lion 500 kV
Red Lion 500/230 kV
Peach Bottom 500/230 kV
Pontiac – Loretto 345 kV
Loretto – Wilton Center 345 kV
Many 230 kV circuits in Dominion
Keeney – Red Lion 230 kV
Harmony – Keeney 230 kV
Linwood – Chichester 230 kV
Seward 230/115 kV
Lee County – Byron 345 kV
Fentress 500/230 kV
Benton – Cook 345 kV
Seward – Johnstown 230 kV

Table 1-35: Transmission Overlay for 30% HOBO Scenario

Transmission Overlay Due to Reliability
Two Axton – Fentress 765 kV
Two Joshua Falls – Fentress 765 kV
Four Fentress 765/500 kV
Two Fentress – Suffolk 500 kV
Rebuild Surry – Chickahominy 500 kV
2nd Fentress – Thrasher 230 kV
2nd Fentress – Landstown 230 kV
Two Cedar Creek – Conastone 500 kV
Joshua Falls – Belmont 765 kV
2nd Red Lion – Keeney 500 kV
2nd Pontiac – Loretto 345 kV
2nd Loretto – Wilton Center 345 kV
2nd Peachbottom 500/230 kV
Transmission Overlay Due to Congestion
3rd Linwood – Chichester 230 kV
3rd Seward 230/115 kV
2nd Lee County – Byron 345 kV
LaSalle – Wilton Center 765 kV
2nd Yadkin – Suffolk 500 kV
Replace Fentress 500/230 kV
2nd Benton – Cook 345 kV
Reconductor Keeney – Harmony 230 kV
Reconductor Seward – Johnstown 230 kV

Figure 1-44: 30% HOBO Transmission Constraints – ComEd

Figure 1-45: 30% HOBO Transmission Overlay – ComEd

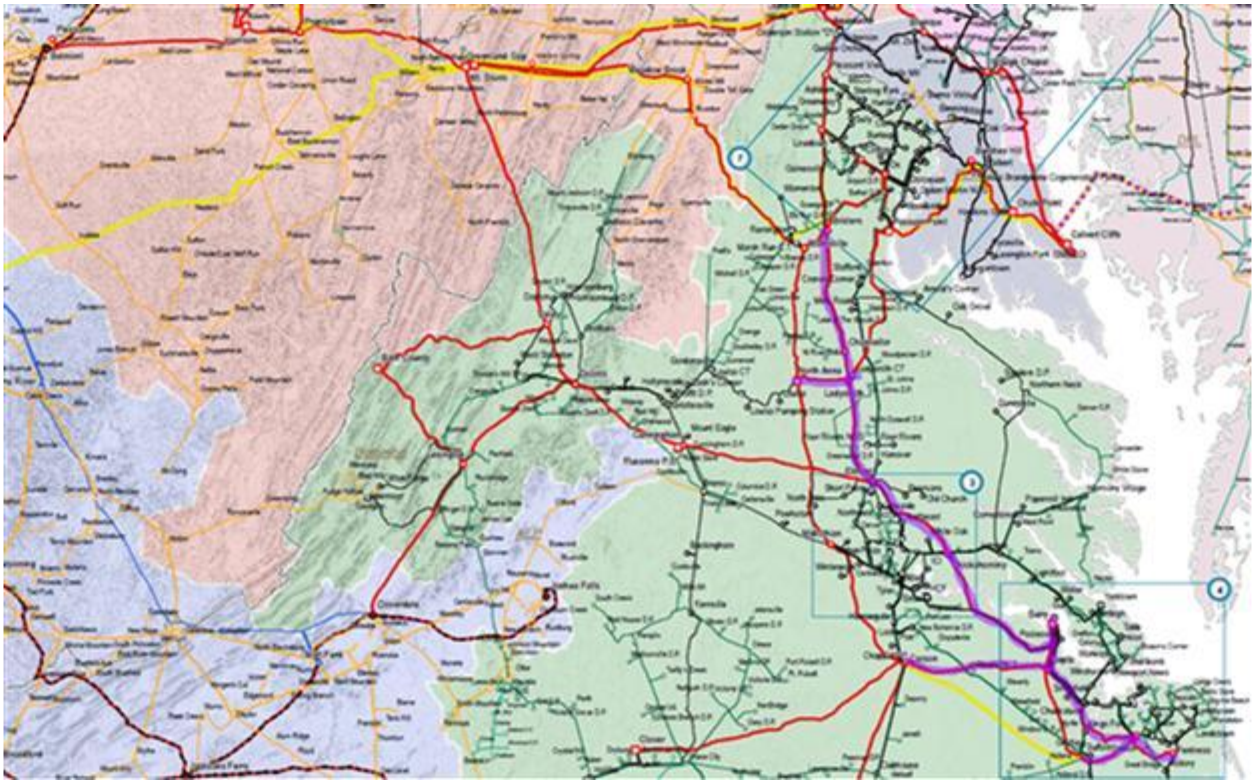

Figure 1-46: 30% HOBO Transmission Constraints – Dominion

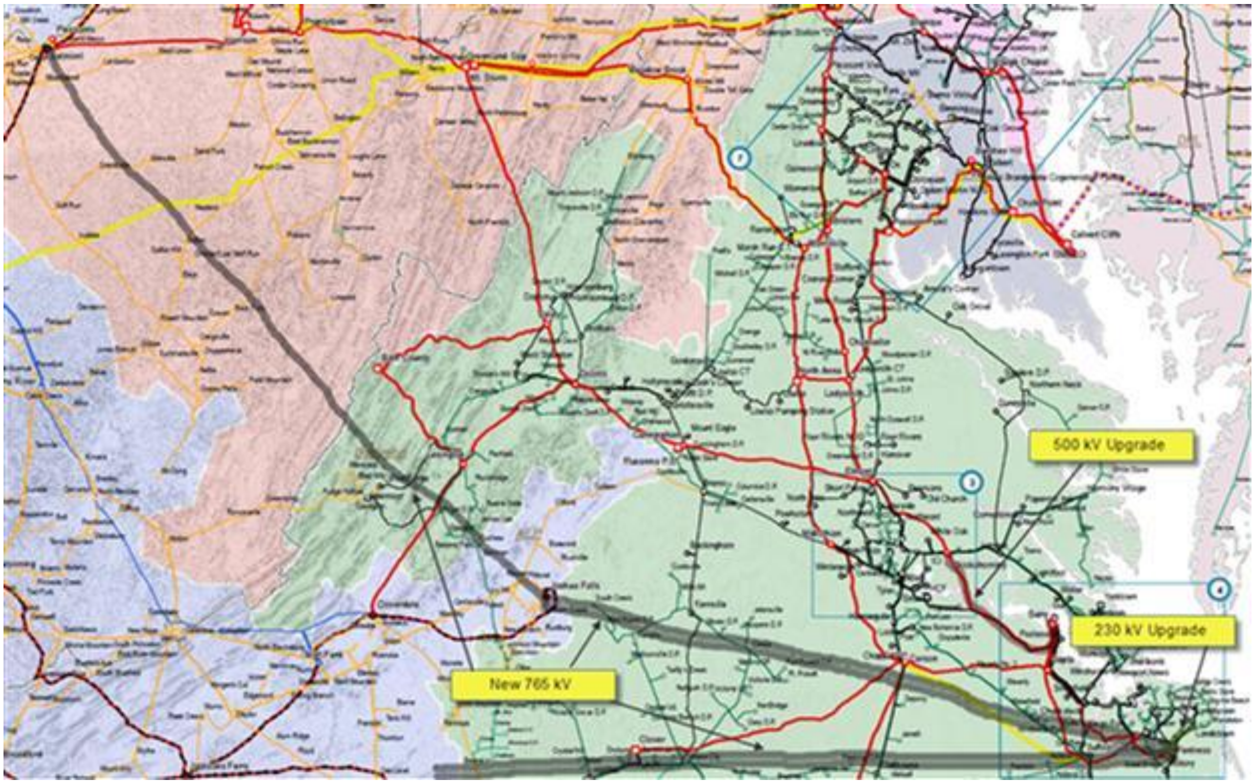

Figure 1-47: 30% HOBO Transmission Overlay – Dominion

Figure 1-48: 30% HOBO Transmission Constraints – Mid-Atlantic Region

Figure 1-49: 30% HOBO Transmission Overlay – Mid-Atlantic Region

Transmission Constraints and Overlays for 30% HSBO Scenario

The transmission constraints and transmission overlays for the 30% High Solar Best Onshore scenario are listed in Table 1-36and Table 1-37. Figure 1-50 through Figure 1-53 show the constraints and overlays geographically.

Table 1-36: Transmission Constraints for 30% HSBO Scenario

Plano – Collins 765 kV
Collins – Wilton Center 765 kV
Wilton Center – Dumont 765 kV
Marysville – Kammer 765 kV
Mountaineer – Belmont 765 kV
Dresden – Elwood 345 kV
Pontiac – Dresden 345 kV
Pontiac – Wilton Center 345 kV
E. Frankfort – Crete 345 kV
Stillwell – Dumont 345 kV
Munster – Burnham 345 kV
Many 345 kV circuit in AEP
Many 345 kV circuits in ComEd
Quad – Sub 91 345 kV
Kanawha River – Matt Funk 345 kV
Fentress – Thrasher 230 kV
Quad Cities – Rock Creek 345 kV
Possum 500/230 kV
Electric Jct. - Lombard 345 kV

Table 1-37: Transmission Overlay for 30% HSBO Scenario

Transmission Overlay Due to Reliability
Quad Cities – La Salle 765 kV
La Salle – Pontiac 765 kV
Pontiac – Greentown 765 kV
Two Greentown – Vassell 765 kV
New Vassell – Star 765 kV
New Pontiac – Sullivan 765 kV
New Star – S. Canton 765 kV
Transmission Overlay Due to Congestion
2nd Quad – Sub 91 345 kV
Reconductor Kanawha R. – M. Funk 345 kV
2nd Fentress – Thrasher 230 kV
2nd Quad Cities – Rock Creek 345 kV
2nd Possum 500/230 kV
2nd Electric Jct. - Lombard 345 kV

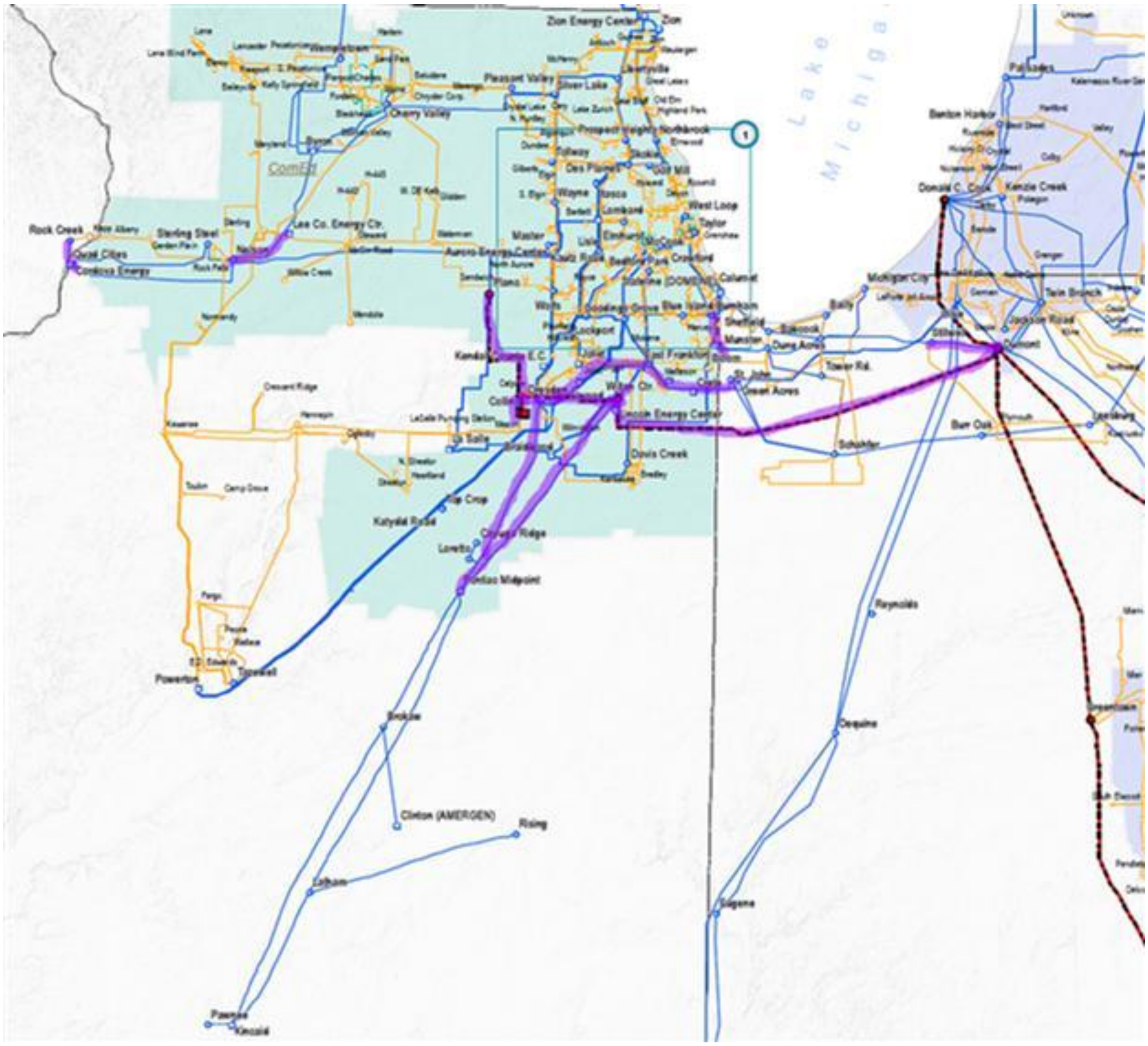

Figure 1-50: 30% HSBO Constraints – ComEd

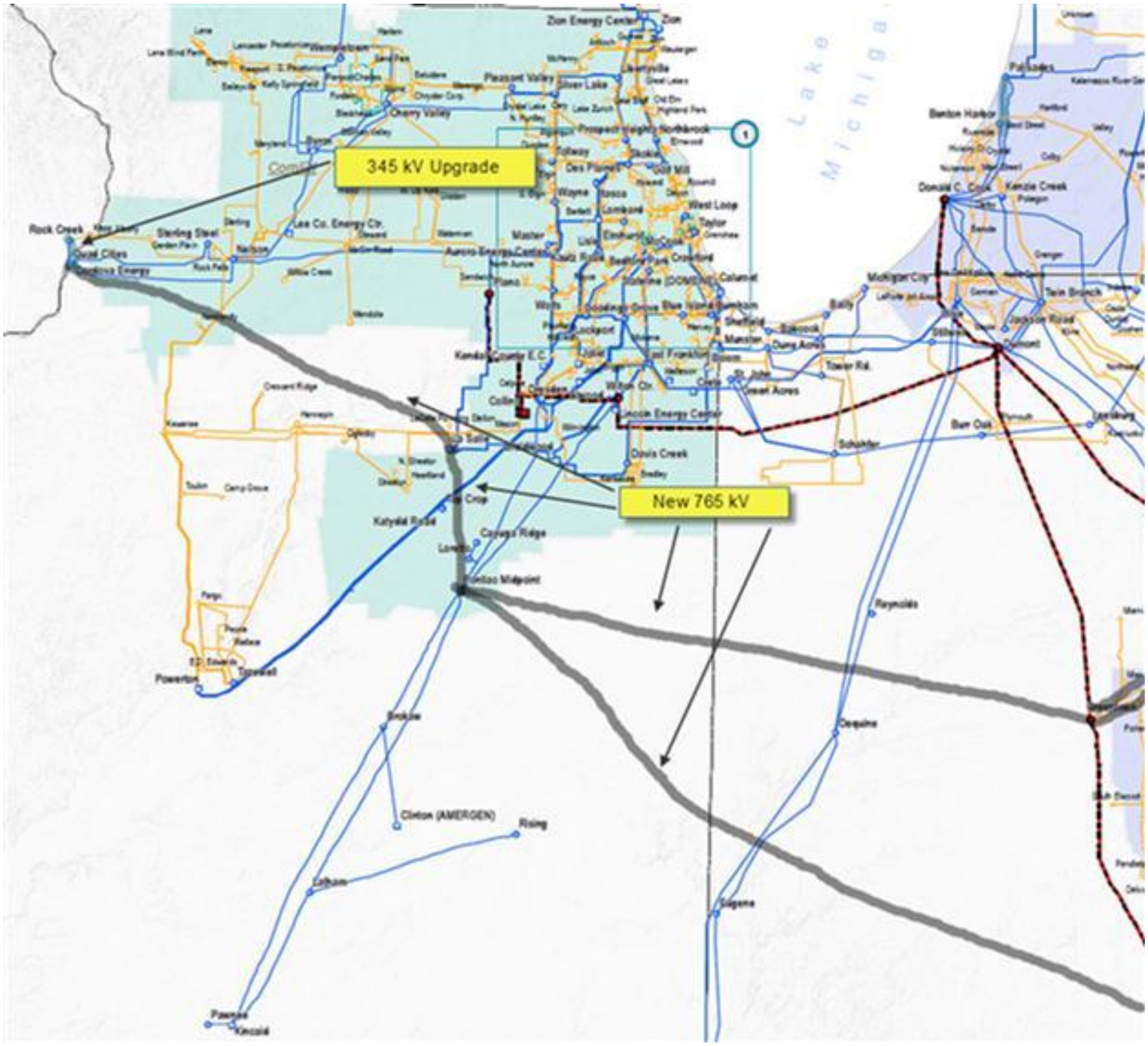

Figure 1-51: 30% HSBO Transmission Overlay – ComEd

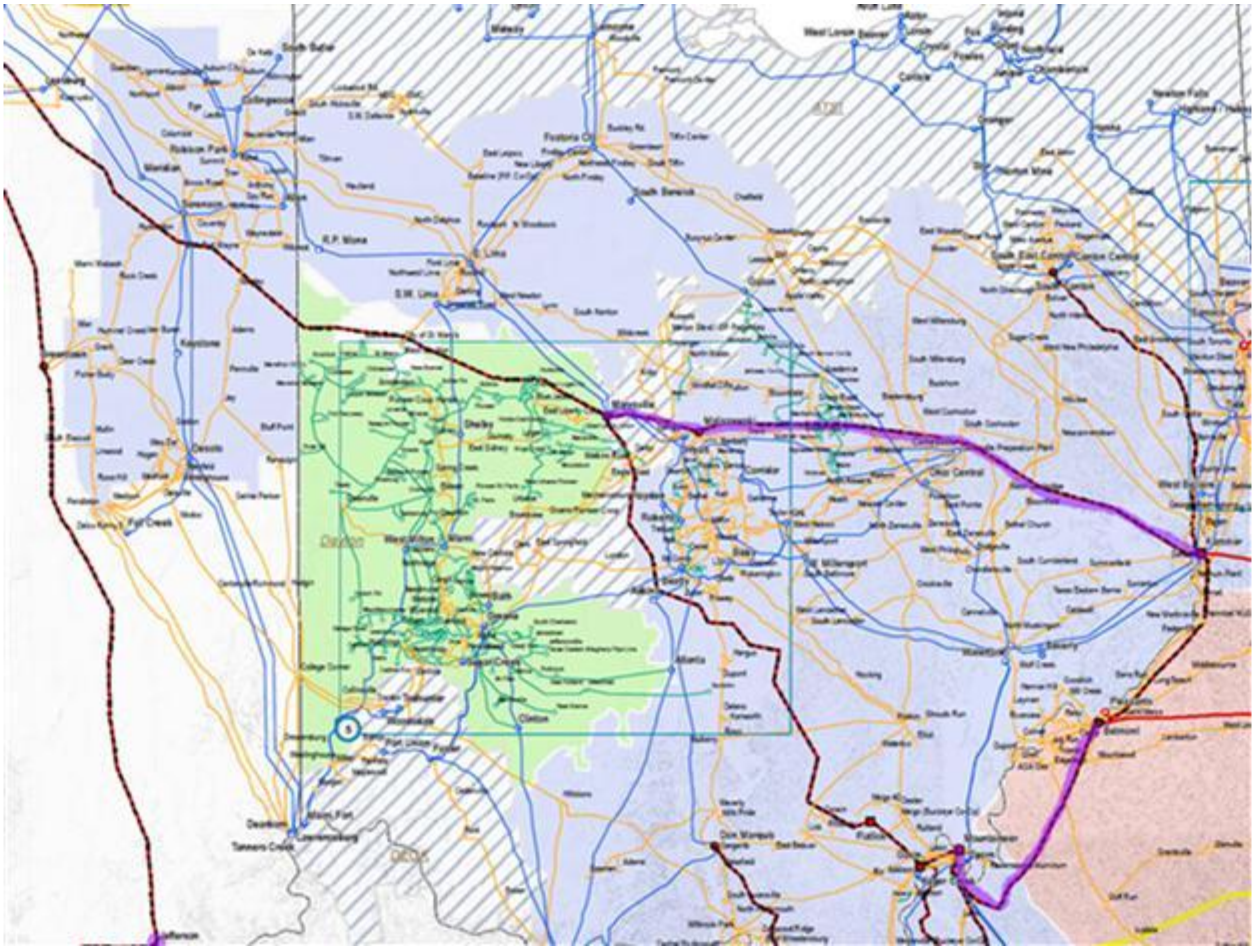

Figure 1-52: 30% HSBO Transmission Constraints – AEP

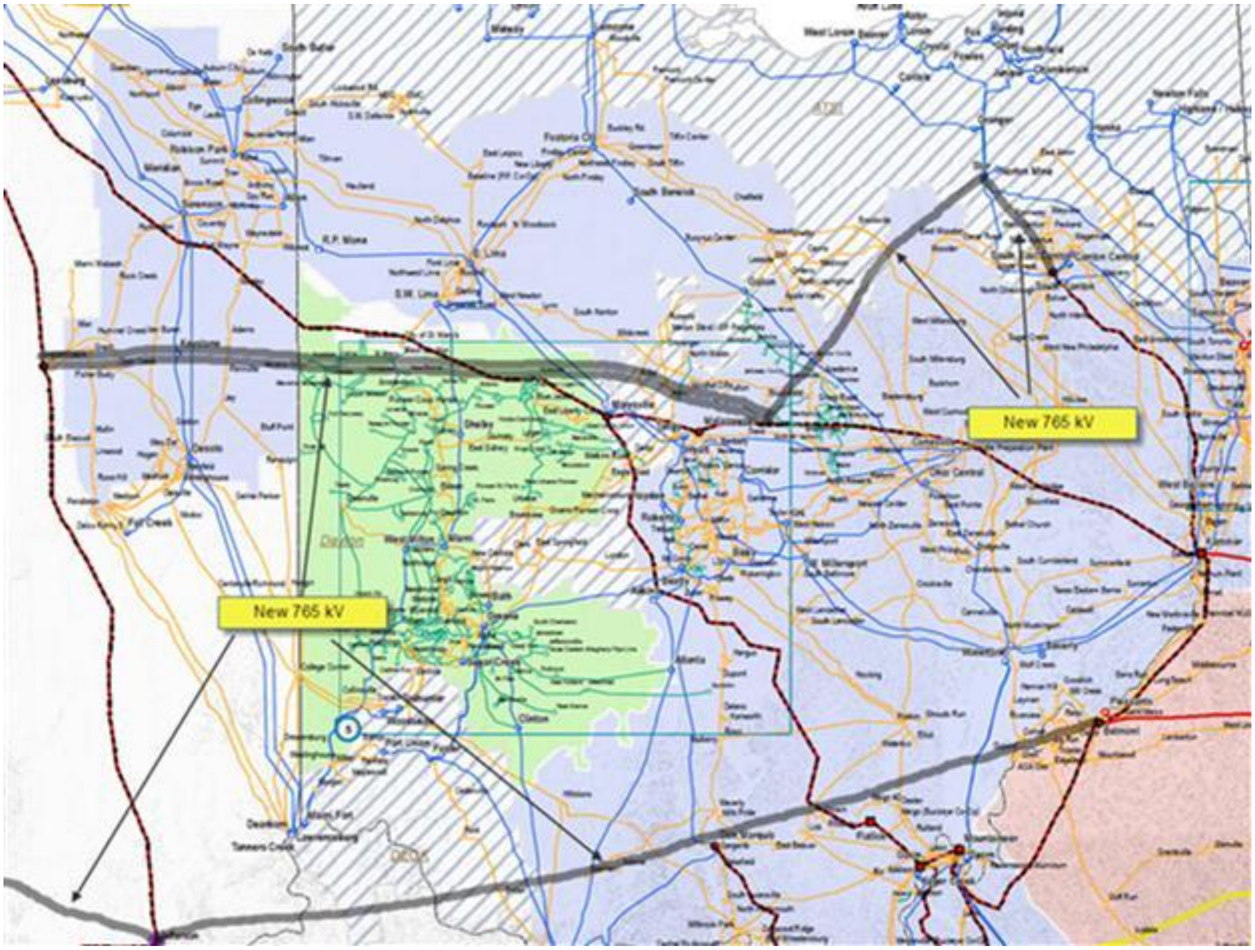

Figure 1-53: 30% HSBO Transmission Overlay – AEP

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