

ENERGY

# Lubbock Power & Light (LP&L) ERCOT Integration Study

ERCOT Regional Planning Group (RPG)

**Prepared by PWR Solutions – A DNV GL Company**

November 20, 2015

# Agenda

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- LP&L System Overview & Background
- LP&L – ERCOT Integration Approach
- LP&L System Evaluation, Transition Roadmap & Upgrades
- Integration Option Development & Screening Assessment
- Shortlisted Option Analyses
  - Steady State Assessment
  - Long-term Load Deliverability Assessment
  - System Strength Assessment
  - Sub-Synchronous Resonance (SSR) Risk Evaluation
  - Budgetary Cost Estimates
- Identification of Preferred Options

# Agenda

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- Additional Analyses for Preferred Options
  - N-1-1 Analysis
  - Panhandle Generation Sensitivity
  - Dynamic Analysis
  - Economic Assessment
- Cost-Benefit Assessment – Preferred Options
- Recommendations
- Q&A

## LP&L System Overview & Background

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- LP&L has served as the city's municipal provider since 1916 when the City of Lubbock established LP&L to manage the electric power of the city.
- LP&L generates and distributes electricity to more than 103,000 customers.
- LP&L operates within certificated areas established by the Public Utility Commission located within the Lubbock city limits.
- In 2010, LP&L purchased the majority of Xcel Energy's distribution assets located within the Lubbock city limits making it the primary provider of electric service in the city.
- LP&L is associated with the West Texas Municipal Power Agency (WTMPA). Member cities that include Lubbock, Brownfield, Floydada and Tulia.
- City of Lubbock requested PUCT to direct ERCOT to evaluate LP&L integration into ERCOT (Texas Grid) via a detailed study
  - <http://www.lpandl.com/energy-services/2019/>
- On September 24, 2015, PUCT instructed ERCOT to study the impact of integrating LP&L into the ERCOT grid
- LP&L engaged PWR Solutions to perform an independent evaluation of LP&L integration to ERCOT – PWR analysis expected to inform the ERCOT study

# ERCOT Integration Approach

**Guiding Principle: Identify most cost-effective solution to reliably integrate LP&L system into ERCOT .....**

LP&L System  
Performance &  
Adequacy  
Assessment

Identification of  
source/sink  
locations on  
ERCOT/LP&L  
- Integration  
Option  
Development

Steady state  
Screening  
Assessment  
- Option  
screening & fine-  
tuning

Detailed Analysis  
- Steady State  
- System  
Strength  
- SSR  
- Long-term load  
serving capability  
- Cost Estimates

Preferred Options  
- N-1-1 Analysis  
- PH Gen  
Sensitivity  
- Dynamic  
Assessment  
- Economic  
Assessment

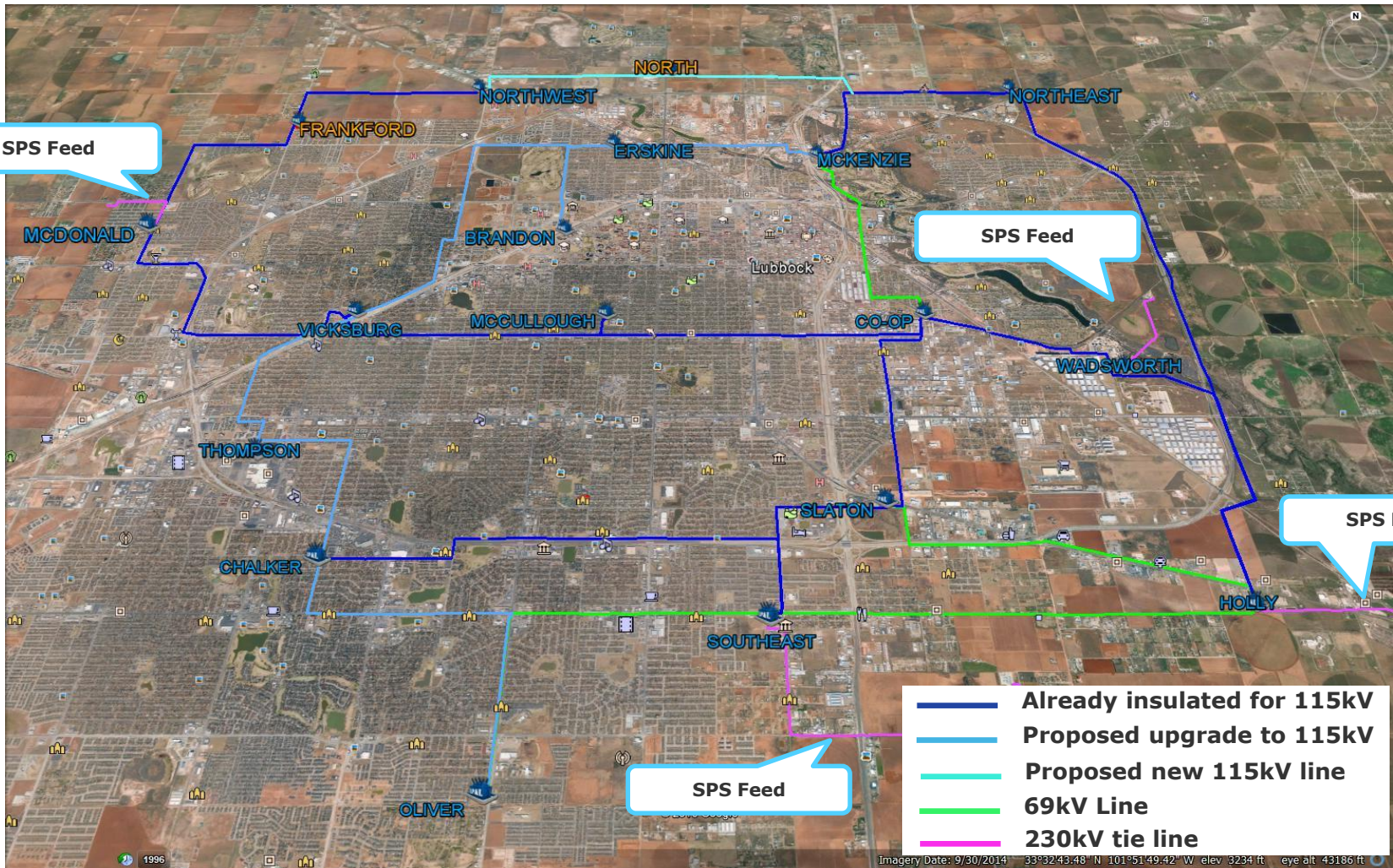
**..... While evaluating the long-term impact/benefit of each solution on both systems when treated as ONE.**

## LP&L System Overview, Transition Roadmap & Upgrades

- Based on initial discussions with PUCT, LP&L anticipates a potential ERCOT integration timeline between 2019-2021
- 2021 chosen as the study year for the reliability & economic studies performed
  - No material difference in the ERCOT transmission topology in the vicinity of LP&L system between 2019 & 2021 – no change in selected options expected between 2019 & 2021
  - LP&L peak system load expected to be higher for 2021 – integration option selected should be designed to account for the higher load in case of slippage in the integration schedule
  - Study year of 2021 accounts for certain LP&L generation unit retirements – thereby presenting a more conservative scenario from a planning perspective
- Based on data provided by LP&L, 2021 load levels on the LP&L system expected to be between 466MW to 593.5MW – all fed off of 69kV transmission system per current design
  - Business as Usual (BAU) load forecast: 466MW
  - High Growth load forecast: 593.5MW
  - Future LP&L load: 200MW (“Additional LP&L Load”)
- LP&L indicated that most of the existing 69kV stations and transmission lines are expected to be insulated for 115kV by the time of ERCOT integration



# LP&L System Overview ,Transition Roadmap & Upgrades



**Current LP&L System & Planned Capital Improvements**

# LP&L System Overview ,Transition Roadmap & Upgrades

## ■ LP&L Transition Roadmap & Upgrades Assessment

- Comparative analysis performed for the LP&L system for two (2) potential scenarios
  - Scenario #1: LP&L system continues to operate at 69kV at time of ERCOT integration and beyond
  - **Scenario #2: LP&L system is configured to have a 115kV outer loop surrounding a 69kV inner loop**
    - Take advantage of the planned capital improvements to convert 69kV facilities to 115kV
    - Limit the load being served from the 69kV system to 200 MW or lesser from a reliability perspective
    - LP&L's planned transmission upgrades can be utilized to design a 115kV loop surrounding the 69kV footprint
      - Reconfiguration will lead to ~300MW of load being served from 115kV system
      - Inner 69kV loop and outer 115kV loop fed by 345kV sources from ERCOT
    - More robust LP&L internal system to fully leverage the benefit of the ERCOT integration



# LP&L System Overview ,Transition Roadmap & Upgrades

## ■ LP&L Transition Roadmap & Upgrades Assessment

- Analysis focused on performance of the LP&L system for both scenarios under multiple contingency events
  - NERC category P1 and P7 (ERCOT\_1)
  - NERC category P3 (G-1+N-1)
  - NERC category P6 (N-1-1)
  - A-1+N-1 events (if applicable) – 345/115kV transformers assumed to be applicable for A-1 events
- Business as Usual (BAU) load growth forecast utilized for conducting comparative analysis
  - High load growth scenario expected to yield higher loadings
- Key findings of this comparative analysis utilized to identify which scenario is likely to better serve the LP&L system from a reliability perspective

## LP&L System Overview ,Transition Roadmap & Upgrades

- Numerous NERC TPL-001-4/ERCOT criteria reliability violations observed under Scenario #1
- Scenario #2 observed to address most of the issues affecting reliability of the LP&L system
  - LP&L system modeled per Scenario #2 for conducting the ERCOT integration study
  - Much more cost-effective solution in comparison to LP&L’s original plan of new 230kV loop

Metric	LP&L Remains at 69KV (Scenario #1)	LP&L Transitions to Scenario #2
<b>Thermal Loadings &gt;90% of Rate B under P1, P7, and P3 (G-1+N-1) Conditions</b>	Majority of lines in LP&L	None for BAU Load Forecast; Minimal for BAU Load + Future LP&L Load
<b>Thermal Overloads &gt;90% of Rate B under A-1+N-1 Conditions</b>	Not Applicable	Only related to 345/115kV Transformers; Can be addressed by resizing or using two (2) transformers at each station
<b>Thermal Overloads under P6 (N-1-1) Conditions</b>	Multiple overloads in violation of ERCOT N-1-1 criteria - power flow convergence issues	Only three (3) overloads observed – No violation of ERCOT N-1-1 criteria
<b>Low-voltage violations under P6 (N-1-1) Conditions</b>	Widespread low-voltage violations observed on the LP&L system	Only three (3) stations observed to depict low-voltage issues

### Comparative Analysis – Summary

**Robust LP&L System Design Imperative for Cost-effective & Successful ERCOT Integration**



## Integration Option Development & Screening Assessment

- A minimum of 3 sources to LP&L from ERCOT evaluated across all integration options
  - Two (2) source integration options not deemed a reliable integration plan for LP&L
    - N-1-1 conditions expected to result in loss of 2 source options
    - Loss of load expected to be in excess of ERCOT criteria (300 MW) – LP&L load expected to be close to 466 MW
  - Double circuit 345kV lines also considered to circumvent the N-1-1 issue
    - Potential concerns around the A-1+N-1 conditions still resulting in loss of both sources
    - At best, the two (2) source options will result in LP&L being fed radially from a single source
    - Anywhere from 466 MW – 593 MW worth of LP&L load being fed radially from a single source – unacceptable from a reliability standpoint
- **Currently LP&L is connected to the rest of the SPP system via four (4) 230kV connections**



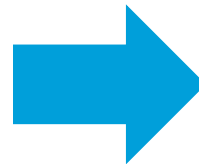
## Integration Option Development & Screening Assessment

- Identification of a list of potential stations on the LP&L system which could serve as POIs with ERCOT
  - Ability to accommodate 345kV interconnections from ERCOT including line terminations and step-down transformers
  - Ability to acquire right of way (ROW) for 345kV lines in vicinity of the station
  - Ability of existing 69kV equipment to be operated at 115kV
  - Ability of the station to be upgraded incrementally if required
  - Potential for land acquisition at the station in case upgrades are required
  - Anticipated load growth in the LP&L system
    - E.g. higher load growth anticipated in the West/North-west region
  - Detailed questionnaire provided to LP&L to acquire additional data associated with these stations
- Three (3) stations are ultimately shortlisted for interconnection with ERCOT
  - Existing **Wadsworth Sub**, planned **North Sub** and **new 345/115kV sub station south of Oliver Sub**
    - Wadsworth – East Interconnection, North Sub – North/West Interconnection & New sub south of Oliver – South Interconnection

# Integration Option Development & Screening Assessment

- Sixteen (16) 345kV stations identified as candidates on the ERCOT system as potential interconnection points for LP&L integration
- Preferred stations derived from the candidate stations based on the following
  - Geographical proximity to LP&L stations
  - System strength at the particular station
  - Potentially redundant options i.e. one between Windmill & Ogallala

Group	ERCOT Station Name	Shortlisted
1	WINDMILL	N
	OGALLALA	Y
	TULE CANYON	Y
	WHITE RIVER	N
	ABERNATHY	Y
2	COTTONWOOD	Y
	DERMOTT	Y
	SCURRY COUNTY	Y
3	GRASSLAND EXTENSION	Y
	FARADAY	N
	LONGDRAW	N
	GRELTON	Y
4	ODESSA	N
	FALCON SEABOARD	Y
	MORGAN CREEK	N
	TONKAWAS	N



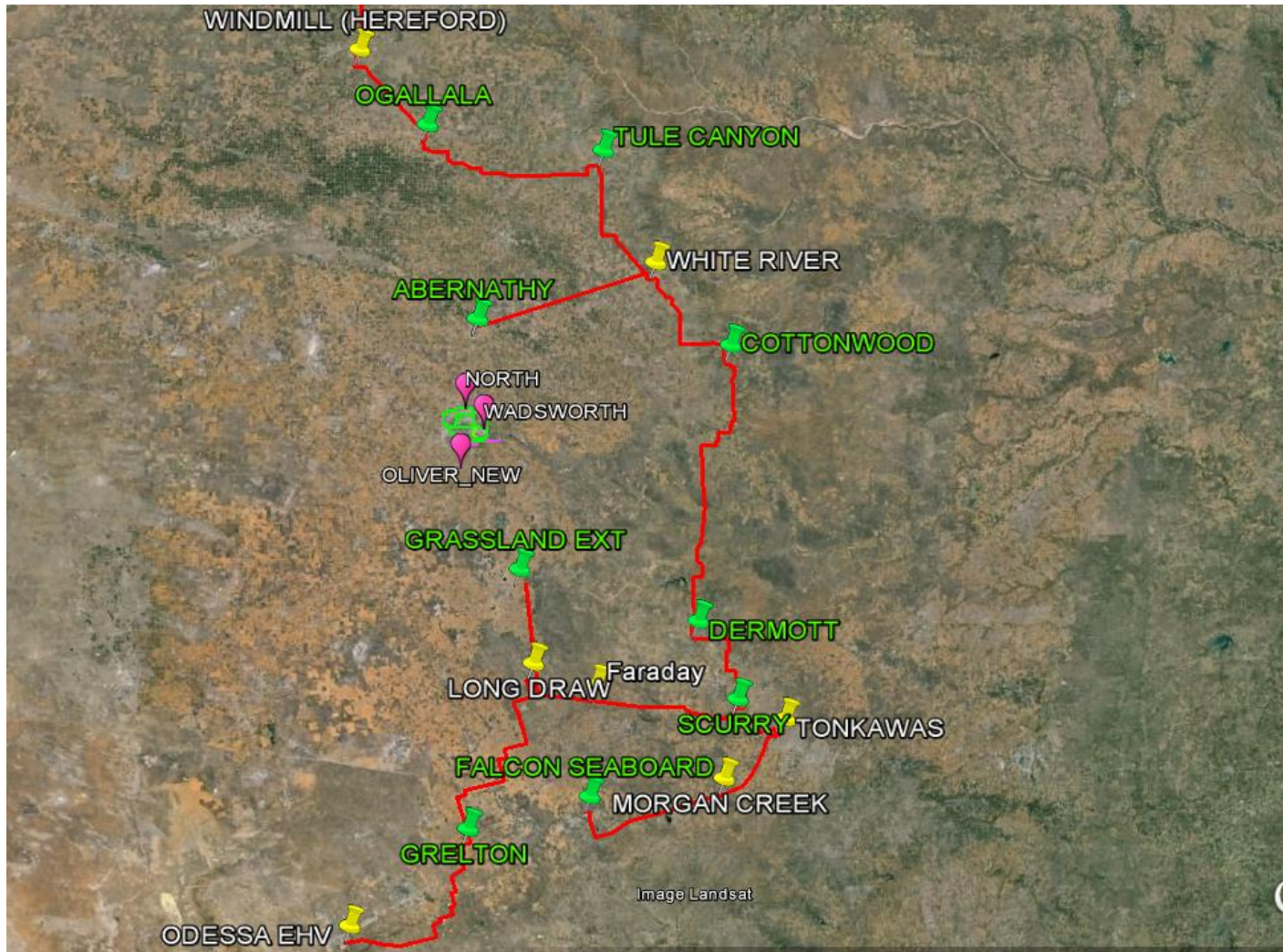
Group	ERCOT Station Name
1	OGALLALA
	TULE CANYON
	ABERNATHY
2	COTTONWOOD
	DERMOTT
	SCURRY COUNTY
3	GRASSLAND EXTENSION
	GRELTON
	FALCON SEABOARD

## Preferred ERCOT Stations

- Note:**
- GRASSLAND EXTENSION is not planned to be an actual/physical substation
- All references to this represent termination location of Sharyland's 345kV line in Grassland region from hereon
- Per Sharyland July 2014 RPG submittal, this line can be extended to connect to the LP&L system as a potential Southern source

## Sixteen (16) Candidate Stations - ERCOT

# Integration Option Development & Screening Assessment



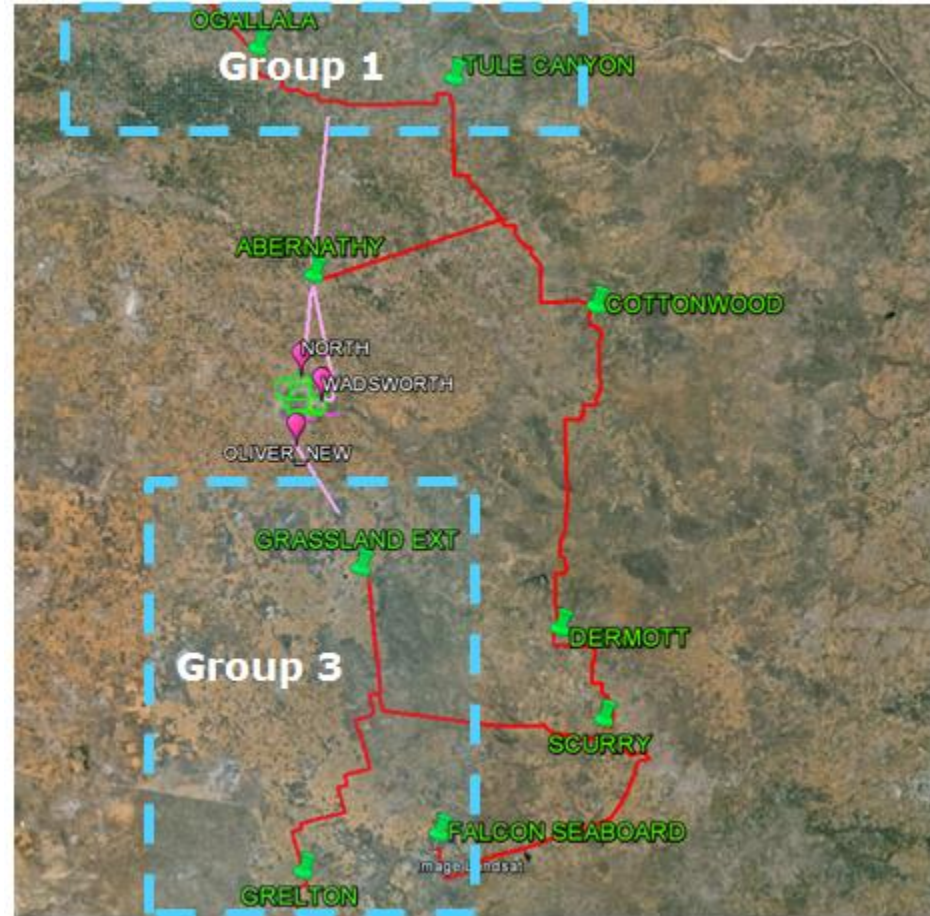
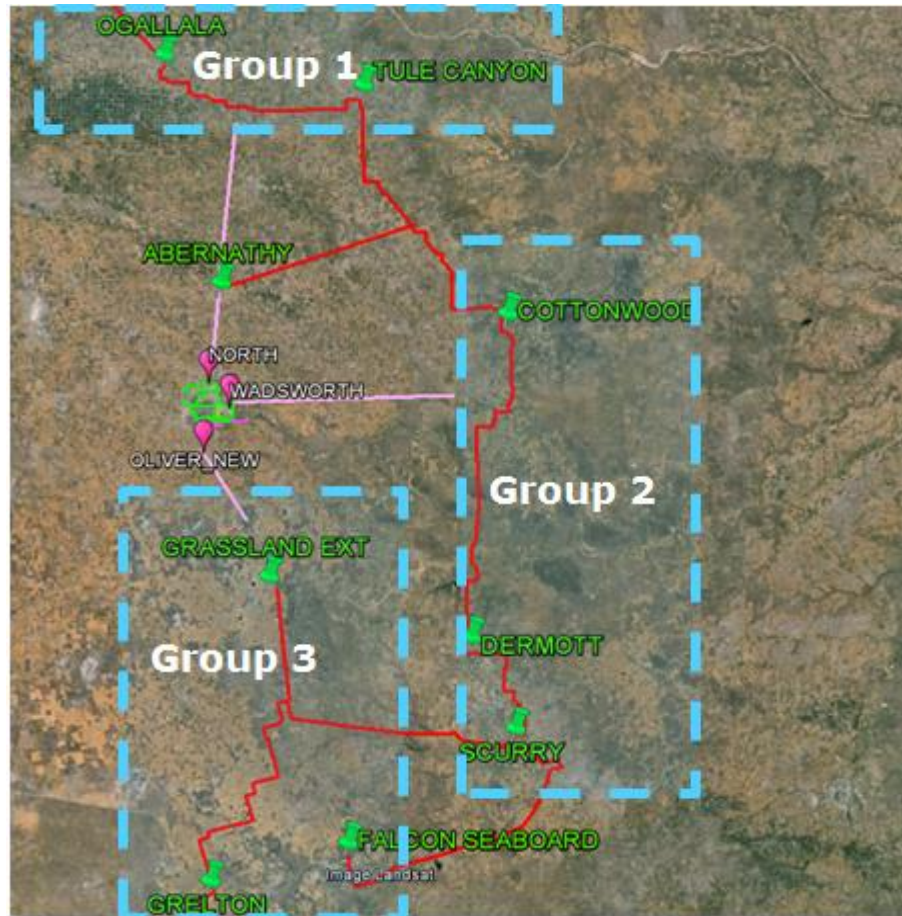
Location of Candidate ERCOT Stations vis-à-vis LP&L (Preferred Stations in Green)



## Integration Option Development & Screening Assessment

- 115kV interconnections to ERCOT with the 345/115kV transformations being performed at the ERCOT station locations also considered– to evaluate a cost-competitive option in comparison to 345kV interconnections
  - N-1-1 and A-1+N-1 conditions lead to LP&L system being fed from one 115kV line
  - Not enough capacity to reliably serve LP&L load in the long term
  - Low voltage issues for the LP&L system especially for the longer distance 115kV lines
  - No major reliability benefits to ERCOT system with the 115kV connections
    - System strength benefits to be significantly reduced
    - Voltage stability benefits for Panhandle region non-existent
- 345kV interconnections to LP&L with 345/115kV transformations at the LP&L POIs the preferred approach
  - All relevant and non-redundant combinations across Groups 1-3 utilized to develop LP&L integration options
  - Total of **36 interconnection options** included for the screening assessment

# Integration Option Development & Screening Assessment



**Integration Option – Illustrative Example #1      Integration Option – Illustrative Example #2**

Options with and without a connection from Group 1 to Abernathy considered

# Integration Option Development & Screening Assessment

## ERCOT POIs Prior to Screening Study

Group	ERCOT Station Name
1	OGALLALA
	TULE CANYON
	ABERNATHY
2	COTTONWOOD
	DERMOTT
	SCURRY COUNTY
3	GRASSLAND EXTENSION
	GRELTON
	FALCON SEABOARD



Group	ERCOT Station Name
1	OGALLALA
	ABERNATHY
2	COTTONWOOD
	DERMOTT
3	GRASSLAND EXTENSION

## ERCOT POIs After Screening Study

### Screening Assessment – Salient Features

- Evaluation of all 36 interconnection options from a normal operation standpoint
  - Further eliminate any redundant options
- A-1+N-1 assessment for all 36 interconnection options (given the normal operation flows, the A-1 condition was deemed to be more critical than a G-1 internal to LP&L)
  - Evaluate need for additional 345/115kV autos to comprise option definition
  - Evaluate need to consider 4 source options along with 3 source options
- Panhandle zero wind sensitivity to evaluate reliance of Panhandle interconnections on wind generation
  - 15% Panhandle wind assumed in the base assessment

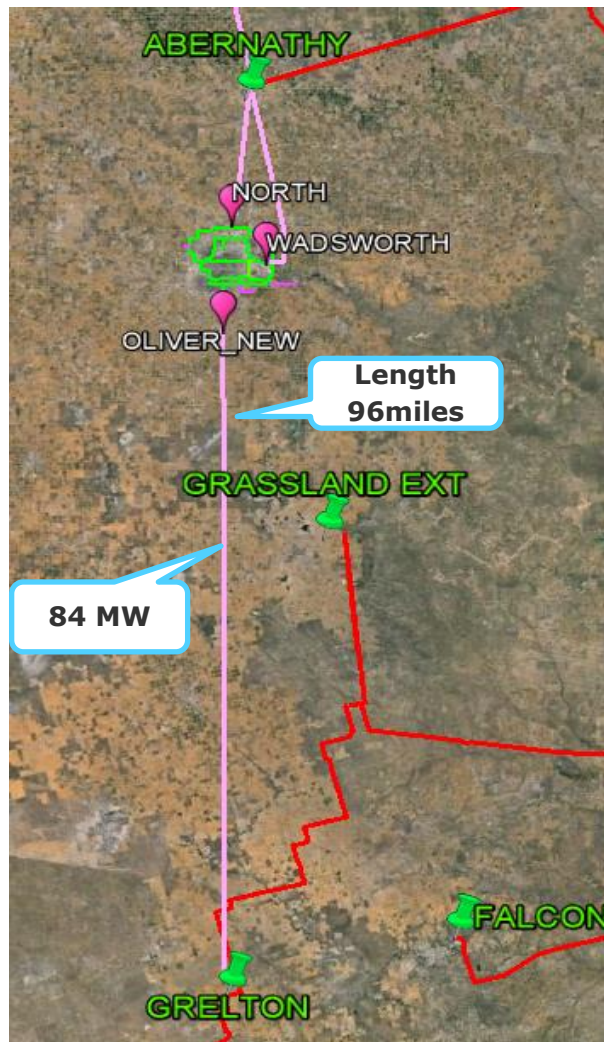
### **Twenty Two (22) options shortlisted for detailed study**



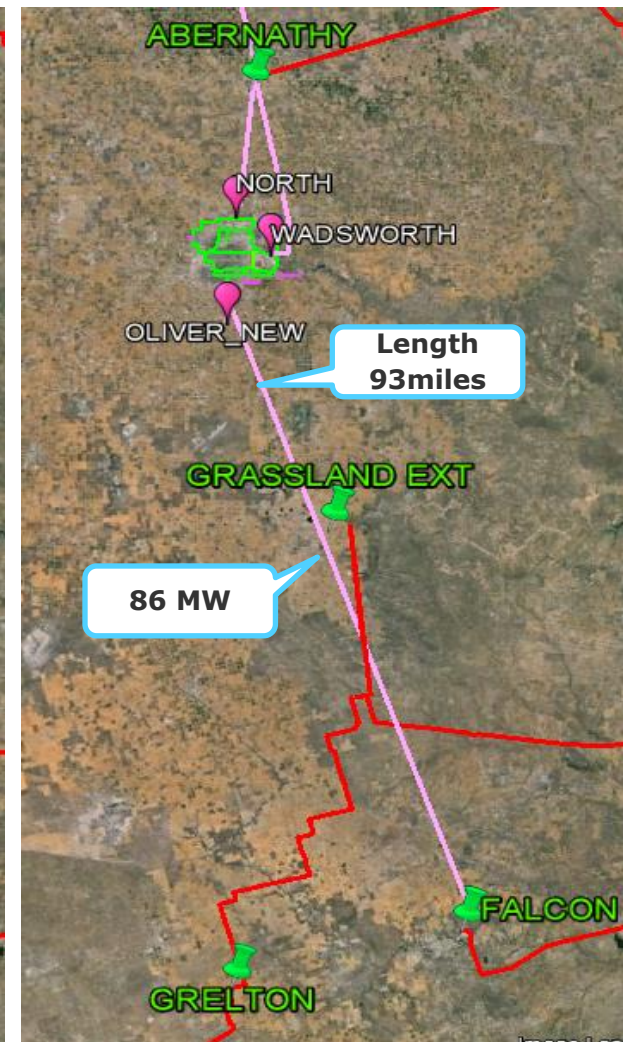
# Integration Option Development & Screening Assessment



Option# 34



Option# 35



Option# 36

## Steady State Assessment – Interconnection Options

- As mentioned previously, 22 options are included for the steady state study
- ERCOT Steady State Working Group (SSWG) 16DSB 2021 Summer Peak case utilized for developing the study model
  - All generation resources meeting Section 6.9 requirements of ERCOT planning guide incrementally modeled in the case
  - Wind generation resources in Panhandle/West region dispatched at 15%
  - Antelope gas generation units kept offline for the screening study
    - Sensitivity around Antelope (Elk) generation unit dispatch studied for preferred options
- LP&L system per Scenario #2 with 115kV outer loop and 69kV inner loop
  - Load in LP&L system modeled as per “high load growth” forecast (~593MW)
- ERCOT and LP&L systems interconnected via the 22 options finalized for study
  - Impedances for 345kV lines interconnecting LP&L and ERCOT modeled to be consistent with existing CREZ lines
  - Impedances for the 345/115kV and 115/69kV transformers modeled based on typical design level data provided by vendors

## Steady State Assessment – Interconnection Options

- Load-generation balance in the study cases maintained by scaling loads in the non-study zones based on “diversity factor” analysis
  - West/Far West/North regions in ERCOT identified to be a part of the **“study zone”**
  - Coast/East/North Central/South/South Central regions are in the **“non-study” zone**



**Study & Non-study Zones**

## Steady State Assessment – Interconnection Options

- Steady state analysis involved evaluation of thermal overloads and potential voltage issues under A-1+N-1 and G-1+N-1 conditions, if any
- Methodology A-1+N-1: Loss of a 345/115kV auto transformer followed by:
  - Loss of another line/transformer (including P1 & P7 (ERCOT 1) events)
  - Loss of a single generator (per ERCOT planning guide)
    - Single generator outage within ERCOT system near Lubbock was considered
- Methodology G-1+N-1: Loss of single largest generation unit within LP&L system (78MW unit at McKenzie station) followed by:
  - Loss of another line/transformer (including ERCOT\_1 (P7) and N-1 events (P1))
- **Performance Criteria**
  - Rate B for thermal overloads
    - Loading levels above 85% of Rate B were identified in order to provide 15% margin
      - Margin included to account for operations and future load growth
  - 0.9-1.05 pu for voltage range and 0.07 pu for voltage deviation
  - Non-consequential load loss not acceptable



# Steady State Assessment – Interconnection Options

Option	A-1+N-1		G-1+N-1		Num of Unsolved Contingencies	Num. of Sources into LP&L
	Num Of 115kV Loadings > 85%	Num Of 69kV Loadings > 85%	Num Of 115kV Loadings > 85%	Num Of 69kV Loadings > 85%		
Option #1	0	0	0	0	0	3
Option #2	0	0	0	0	0	
Option #3A*	0	0	0	0	0	
Option #3B*	0	0	0	0	0	
Option #4	0	0	1	0	0	
Option #5	0	0	0	0	0	
Option #6	0	1	2	0	0	
Option #7*	2	0	0	0	0	
Option #8A*	0	0	0	0	0	
Option #8B*	0	0	0	0	0	
Option #9*	0	0	0	0	0	4
Option #10	0	0	0	0	0	
Option #11	0	0	0	0	0	
Option #12	2	0	0	0	0	
Option #13	0	0	0	0	0	
Option #14	0	0	0	0	0	
Option #15	0	0	0	0	0	
Option #16	0	0	0	0	0	
Option #17	0	0	0	0	0	
Option #18	0	0	0	0	0	
Option #19	2	0	0	0	0	
Option #20	2	0	0	0	0	

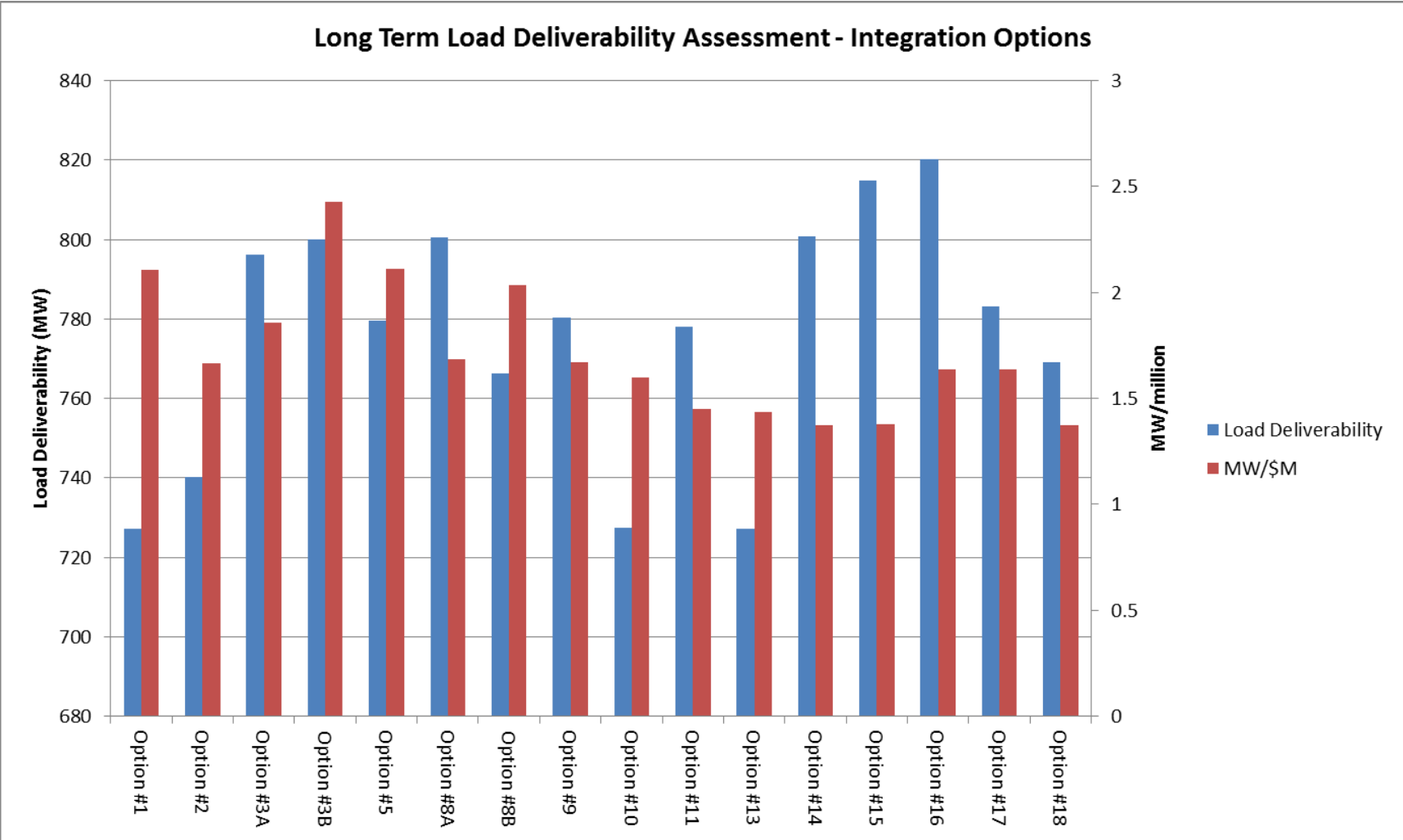
## Option Performance Evaluation – A-1+N-1/G-1+N-1 Analysis

\* Indicates options with partial 345kV loops around LP&L

## Long-Term Load Deliverability Assessment

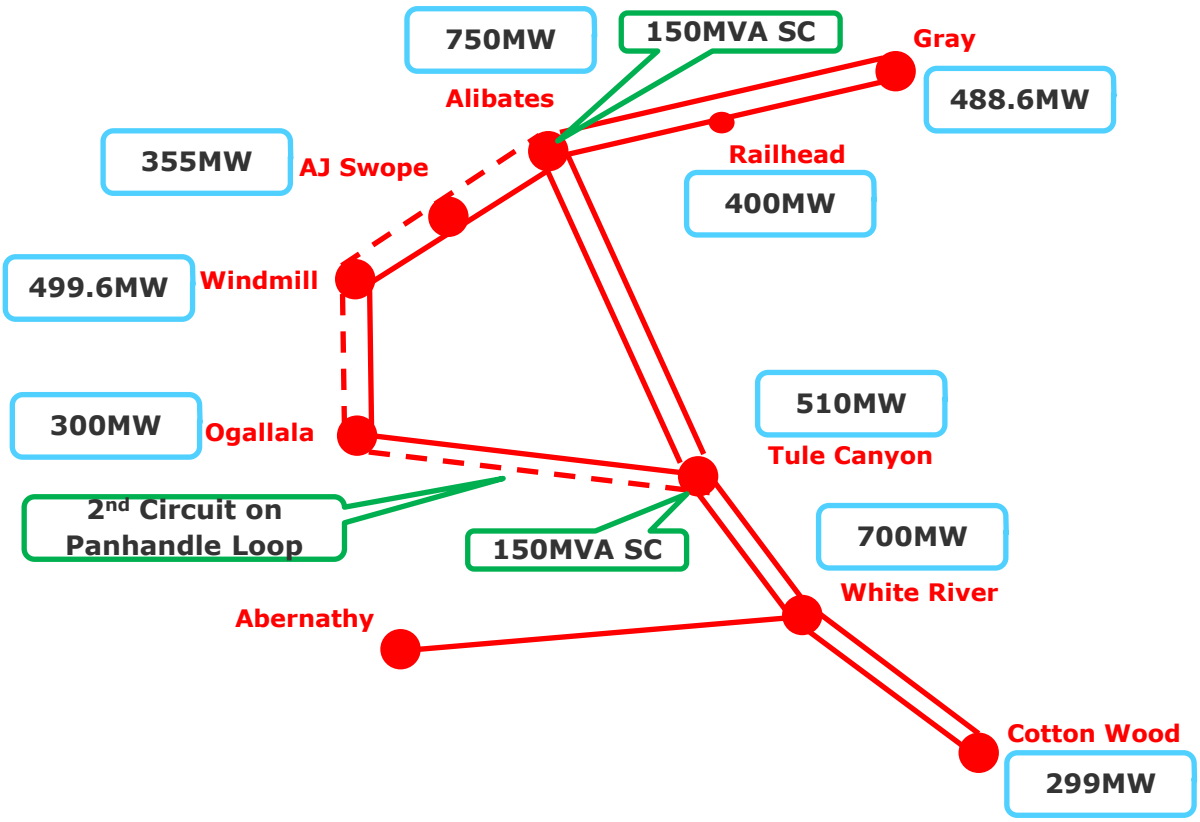
- The following assessments were performed to evaluate long-term load deliverability of the shortlisted sixteen (16) interconnection options (based on results of the steady state assessment)
  - Available Transfer Capability (ATC)
    - Identify potential future thermal limitation (>100% of Rate B)
  - PV analysis
    - Identify potential future voltage stability limitation (voltage collapse)
- Long Term Load Deliverability Performance Criteria
  - Option expected to support long term LP&L load growth i.e. minimum threshold of 700 MW
  - MW/\$M metric also utilized to gauge the relative cost-effectiveness of various options
- G-1+N-1/A-1+N-1 scenarios were analysed for Long-term Load Deliverability
  - Most limiting transfer levels were considered for evaluating options from a thermal and voltage security standpoint
  - LP&L facilities in planning stage not considered as potential constraints for future load serving scenario
    - Scope to size the facility appropriately based on the results of the assessment

# Long-Term Load Deliverability Assessment



**Load Deliverability Assessment, Shortlisted Options, Thermal Standpoint**

# System Strength Assessment – ERCOT Perspective



**ERCOT Panhandle 345kV Transmission System  
with WGR Capacity**

(WGR capacity is based on Latest ERCOT GIS Report at the time of assessment)

- For the purpose of WSCR computation, a total of **4302.2MW** of WGR capacity included on the Panhandle transmission system
- All WGRs included for assessment meet Section 6.9 requirements of ERCOT Planning Guide
- Note that WGR capacity only included for WSCR calculation
- Short-circuit contribution of WGRs not included while computing  $S_{SCMVA}$  at each station
- Fault current contribution from the synchronous condensers modeled to be 1050A at 345kV

# System Strength Assessment – ERCOT Perspective

Description	WSCR with LP&L Generation in Service & Elk Units Offline	WSCR with LP&L Generation & Elk 1 In-service	WSCR with LP&L Generation & Elk 1, 2, 3 In-service
Base Case	1.35	1.44	1.5
Option#1	1.43	1.49	1.54
Option#2	1.48	1.57	1.66
Option#3A	1.55	1.63	1.71
Option#3B	1.48	1.54	1.6
Option#5	1.41	1.48	1.52
Option#8A	1.54	1.61	1.68
Option#8B	1.46	1.51	1.55
Option#9	1.5	1.6	1.68
Option#10	1.44	1.52	1.59
Option#11	1.48	1.57	1.65
Option#13	1.48	1.57	1.65
Option#14	1.51	1.61	1.69
Option#15	1.51	1.61	1.69
Option#16	1.46	1.55	1.62
Option#17	1.43	1.51	1.57
Option#18	1.47	1.56	1.64

## WSCR Assessment - Shortlisted Options (With Sensitivity Around Elk Generation)

# System Strength Assessment – ERCOT Perspective

## WSCR Evaluation – Key Observations

- Base case without LP&L shows a WSCR value of 1.35
- WSCR values increase after integration with LP&L irrespective of the integration option
  - New 345kV lines proposed as a part of LP&L integration lead to increase in  $S_{SCMVA}$  at ERCOT Panhandle stations
  - Generation in Lubbock also leads to marginal increase in  $S_{SCMVA}$
  - WSCR shows higher increment over the base case whenever there is a line connecting Ogallala and Abernathy
  - Presence of 345kV loops around LP&L is also observed to increase WSCR values (e.g. Option#3A)
  - Connection from Dermott instead of Cotton Wood offers no benefit in terms of WSCR
- **In summary, integration of LP&L observed to provide clear benefit to the ERCOT Panhandle transmission system from a system strength standpoint**
- Elk sensitivity expected to have the same relative impact across all options

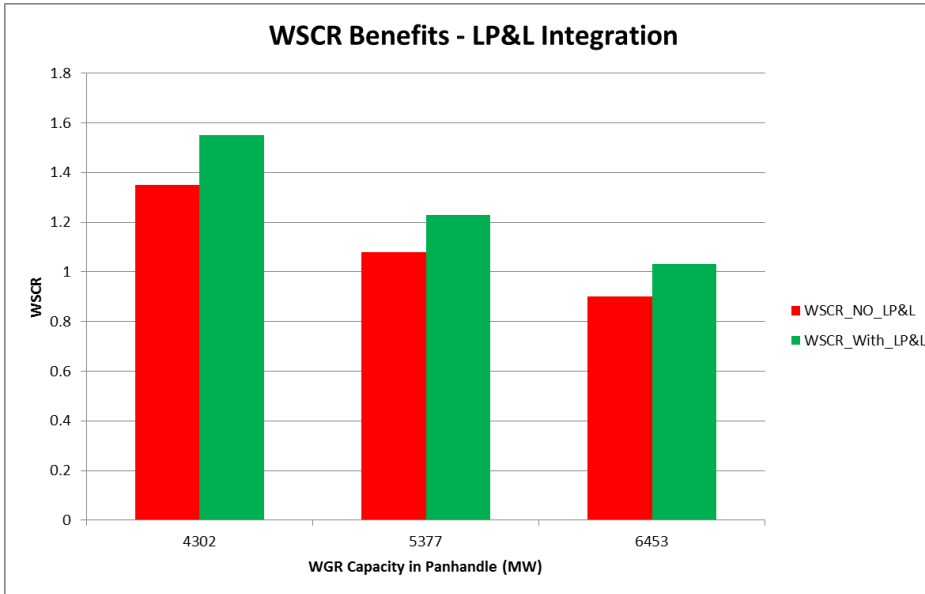
# System Strength Assessment – ERCOT Perspective

## WSCR Evaluation – Benefit Quantification

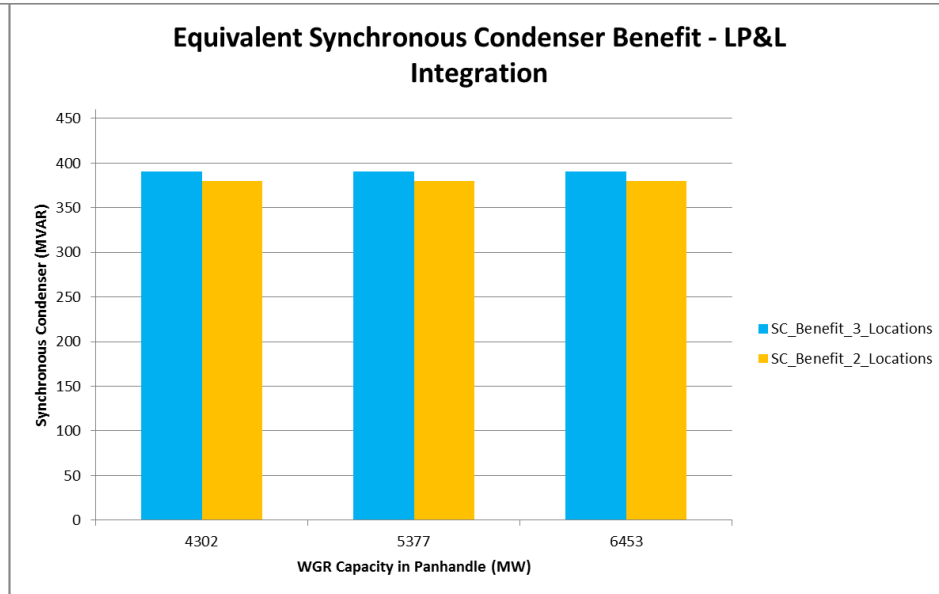
- Increase in WSCR due to LP&L integration is expected to reduce the amount of synchronous condensers required to meet a specific WSCR target
  - As discussed previously, with ~4300MW of WGRs in the Panhandle, the base case WSCR is 1.35
  - With LP&L integrated, the WSCR for the same WGR capacity is 1.55 (best performing option)
  - Estimated that if LP&L was not integrated, there would be need for 390MVAR of additional synchronous condensers to increase the WSCR from 1.35 to 1.55
    - SCs located at 3 stations (Windmill, Ogallala and Gray) for the purpose of this estimation
    - If SCs are at 2 stations (e.g. Windmill/Ogallala or Windmill/Gray), around 380MVAR of capacity is required to realize same WSCR benefit
  - **Thus LP&L integration provides WSCR benefit equivalent to ~390MVAR of synchronous condensers (~\$80M) with the 4300MW of WGR capacity**
    - Sensitivity around LP&L generation off-line also performed
    - Sensitivity around LP&L generation off-line indicates no significant reduction in the SC benefits



# System Strength Assessment – ERCOT Perspective



**WSCR Benefits – Summary**



**Synchronous Condenser Benefits - Summary**

**LP&L integration continues to provide the same WSCR benefit (equivalent to ~390MVAR of SCs) even if the Panhandle WGR capacity increases to ~6500MW**

## System Strength Assessment – LP&L Perspective

- Involves assessment of benefit provided to LP&L by each interconnection option from a system strength standpoint
- Defined a “System Strength Metric” (SSM) for each option
  - SSM expected to be indicative of how strongly a particular option integrates ERCOT and LP&L from an LP&L perspective
- SSM calculation accounts for the following:
  - Short-circuit MVA at each 345kV station serving as POI for the LP&L system
    - 345kV North, Wadsworth, New Oliver, Holly, New McDonald stations
  - Power flow (in MW) into the each LP&L POI from the ERCOT system
- Analytical expression for SSM

$$SSM = \left( \sum_{i=1}^N S_{SCMVAi} \times P_{MWi} \right) / \left( \sum_{i=1}^N P_{MWi} \right)^2$$

Where,

$S_{SCMVAi}$  = Short-circuit MVA at  $i^{th}$  LP&L POI

$P_{MWi}$  = Total MW capacity being injected into the  $i_{th}$  LP&L POI

## System Strength Assessment – LP&L Perspective

Option#	SSM_No_Elk	SSM_With_Elk1	SSM_With_Elk1, 2, 3
1	7.43	8.22	8.96
2	8.81	9.45	10.08
3A	11.6	12.45	13.3
3B	9.96	11.05	12.12
5	7.22	8.07	8.88
8A	10.93	11.63	12.32
8B	9.33	10.27	10.53
9	10.49	11.16	11.81
10	8.18	8.86	9.5
11	8.27	8.92	9.56
13	8.58	9.27	9.96
14	9.04	9.64	10.24
15	9.33	9.92	10.49
16	9.05	9.68	10.28
17	8.14	8.85	9.53
18	8.25	8.94	9.62

**SSM Analysis - Shortlisted Options  
(with Sensitivity Around Elk Generation)**

## SSR Risk Evaluation – ERCOT Perspective

- Benefit of each interconnection option in reducing SSR risk for generation resources in the vicinity of LP&L region also evaluated
  - Lowest “N-X” outage count required to establish a radial connection between each ERCOT station and nearest series compensated lines is determined for the base case
  - Determined whether the lowest “N-X” count for a particular ERCOT station increases after implementing an LP&L integration option
  - If the lowest “N-X” count for a particular station is observed to increase, the option is marked to benefit that station from an SSR standpoint

Stations Included for SSR Assessment
Gray
Raihead
Alibates
AJ Swope
Windmill
Ogallala
Tule Canyon
White River
Abernathy
Cotton Wood
Long Draw

### ERCOT Stations for SSR Benefit Evaluation

## SSR Risk Evaluation – ERCOT Perspective

- All interconnection options that involve a connection from Ogallala to Abernathy provide a benefit to all Panhandle options from an SSR standpoint

Option #	No of Stations Benefited	Names of Stations Benefited
1	3	AB, CW, LD
2	11	GR, RH, ALI, AJ, WM, OG, TC, WR, CW, AB, LD
3A	11	GR, RH, ALI, AJ, WM, OG, TC, WR, CW, AB, LD
3B	2	AB, LD
5	3	AB, CW, LD
8A	11	GR, RH, ALI, AJ, WM, OG, TC, WR, CW, AB, LD
8B	3	AB, CW, LD
9	11	GR, RH, ALI, AJ, WM, OG, TC, WR, CW, AB, LD
10	4	AB, CW, WR, LD
11	11	GR, RH, ALI, AJ, WM, OG, TC, WR, CW, AB, LD
13	11	GR, RH, ALI, AJ, WM, OG, TC, WR, CW, AB, LD
14	11	GR, RH, ALI, AJ, WM, OG, TC, WR, CW, AB, LD
15	11	GR, RH, ALI, AJ, WM, OG, TC, WR, CW, AB, LD
16	4	AB, CW, WR, LD
17	4	AB, CW, WR, LD
18	11	GR, RH, ALI, AJ, WM, OG, TC, WR, CW, AB, LD

### SSR Risk Evaluation for ERCOT Generation Resources

## SSR Risk Evaluation – LP&L Perspective

- SSR screening assessment for the three (3) LP&L generation facilities (McKenzie/ Brandon/ Holly) performed
  - Three (3) series compensated lines in ERCOT included for SSR screening
    - 345kV Tule Canyon – Tesla
    - 345kV Dermott – Clear Crossing
    - 345kV Edith Clarke – Clear Crossing
  - For each LP&L generation facility, lowest “N-X” outage count required to establish radial connection to the aforementioned lines in ERCOT is determined
    - “N-X” computation performed for all sixteen (16) integration options
  - Requires N-8 or greater concurrent outages to result in the LP&L generation facilities to be radially connected to series compensation across all options
  - Potential for SSR risk (if any) expected to be addressed via procedural mitigation in the form of outage coordination
    - Based on latest language in ERCOT SSR Workshop & NPRR562
  - SSR risk for LP&L generation facilities may have to be evaluated further via detailed screening/EMT simulations for the recommended options

## LP&L Generation – SSR Risk Evaluation

Option #	Holly	McKenzie	Brandon
1	N-10	N-9	N-10
2	N-10	N-10	N-11
3A	N-13	N-11	N-12
3B	N-12	N-10	N-11
5	N-8	N-9	N-10
8A	N-10	N-11	N-12
8B	N-10	N-10	N-11
9	N-11	N-10	N-11
10	N-10	N-10	N-11
11	N-10	N-11	N-12
13	N-10	N-11	N-12
14	N-10	N-11	N-12
15	N-10	N-11	N-12
16	N-10	N-10	N-11
17	N-8	N-10	N-11
18	N-8	N-11	N-12

### LP&L Generation – SSR Risk Assessment Summary

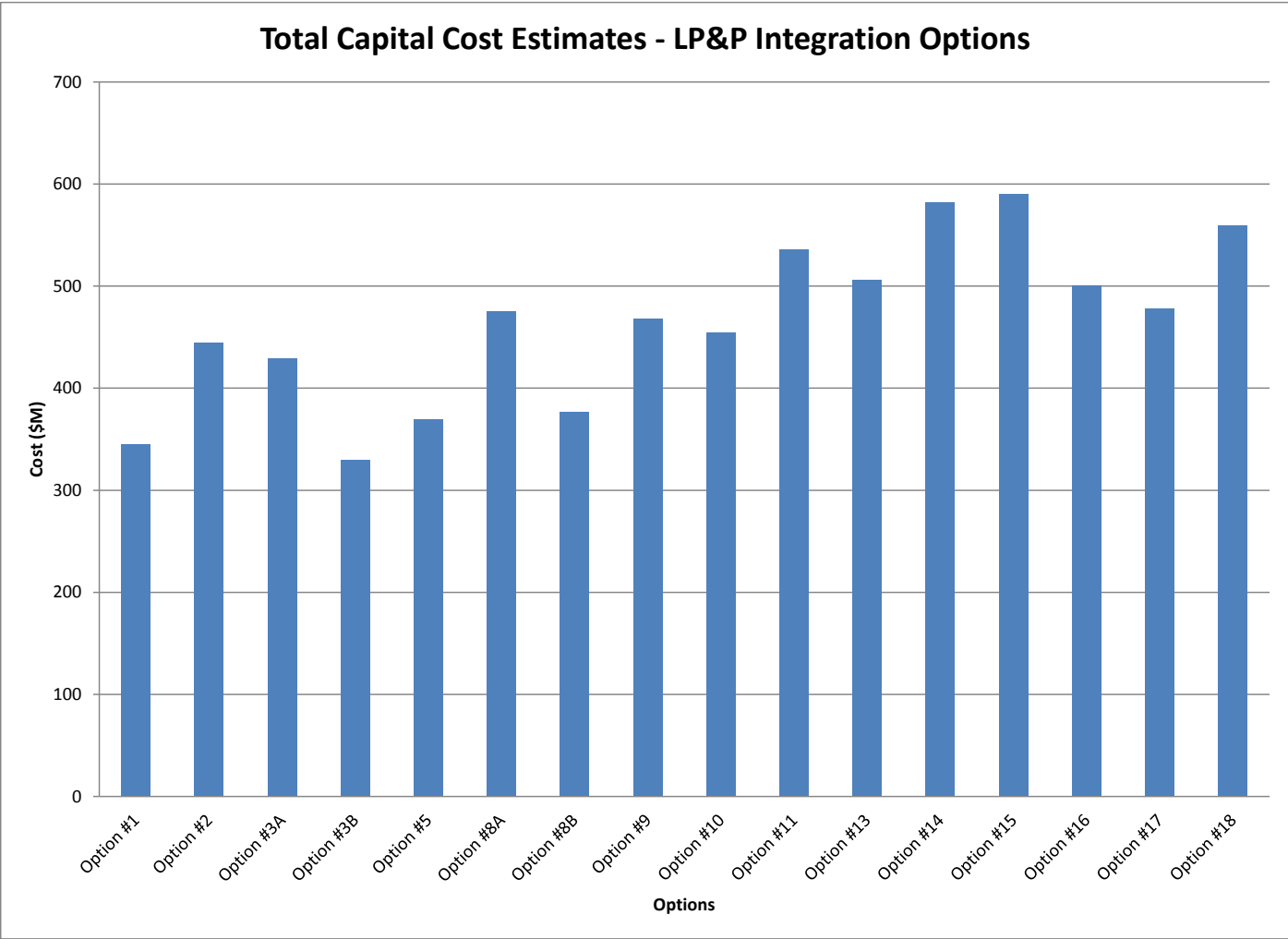
## Budgetary Cost Estimates – Basis Assumptions

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- 345kV transmission line estimates based on ERCOT rural average cost estimates (\$1.95M/mile)
- New 345kV stations assumed to be 6-breaker ring bus and ERCOT average cost estimates utilized @ \$15.94M
- New 115kV stations assumed to be 6-breaker ring bus @ \$9.05M
- ERCOT average cost estimates for 345/138kV autos utilized for the 345/115kV autos (rating < 700 MVA)
- Land acquisition costs for new 345/115kV stations included (\$500K)
- Cost estimates for new 115kV lines obtained from LP&L (\$1.6M/mile)
- Existing LP&L station expansion costs not included – expected to be minimal in terms of ERCOT integration per discussion with LP&L



# Budgetary Cost Estimates

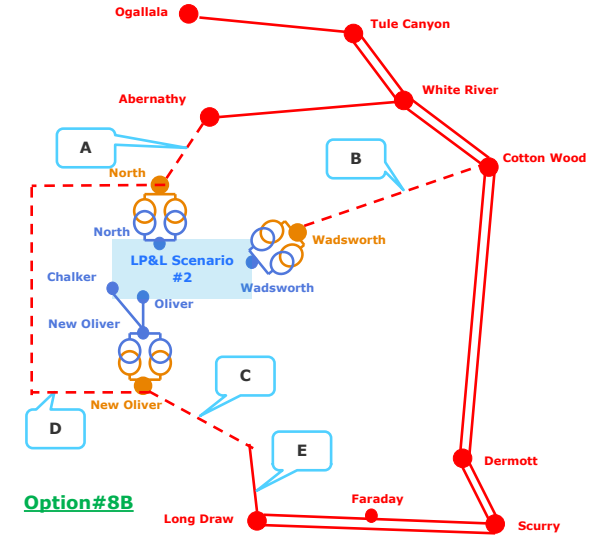
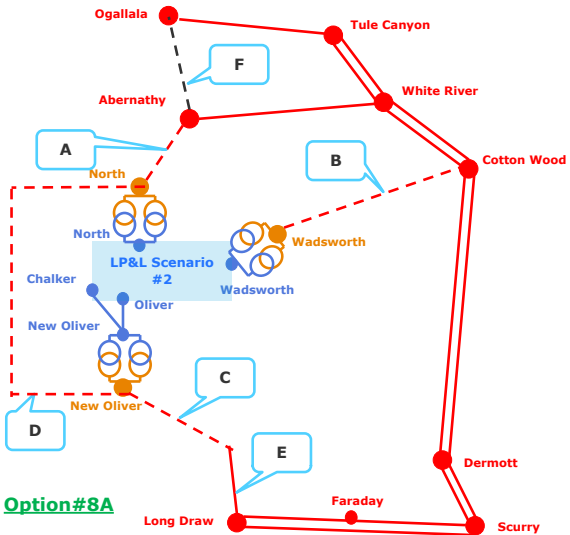
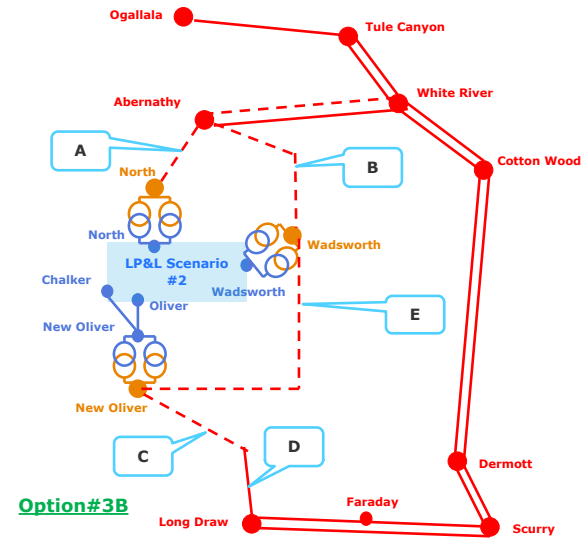
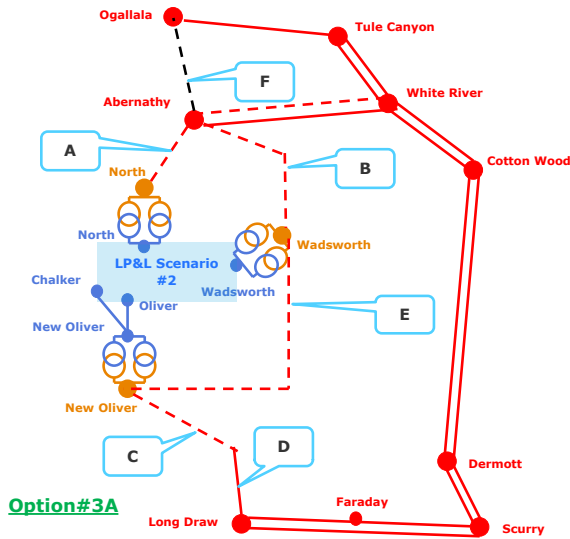


## Budgetary Cost Estimates - Shortlisted Options

## Identification of Preferred Options

- Sixteen (16) integration options observed to result in acceptable steady state performance based on conditions studied
  - NERC TPL-001-4 & ERCOT Planning Criteria standpoint
- Following factors utilized to further assess the relative merits of each of the sixteen (16) options
  - Long term load serving capability for LP&L system
  - System Strength benefits to LP&L & ERCOT
  - SSR impacts to both LP&L & ERCOT
  - Cost estimates & cost-effectiveness
- Options 3A and 8A identified as top performing options based on the metrics outlined above
  - Options 3B and 8B subsets of Options 3A and 8A respectively – **Minimum set of transmission facilities required to integrate LP&L into ERCOT**
  - 345kV Ogallala – Abernathy line incremental addition to Options 3B/8B to transition to 3A/8A respectively i.e. phased approach
  - **Options 3A, 3B, 8A and 8B identified as preferred options**

# Identification of Preferred Options





## Additional Analysis Preferred Options - N-1-1 Assessment

Option	Num Of Xformers Violations	Num Of Violations Of Proposed Lines	Num Of Violations Of Existing Lines	Length of Existing 115kV Lines Overloaded (miles)	Length of Existing 69kV Lines Overloaded (miles)	Length of Proposed 115kV Lines Overloaded (miles)	Max Load Shed 115kV (MW)	Max Load Shed 69kV (MW)	Num of unsolved contingencies	Num of Sources into LP&L
Option #3A	0	0	1	0	3.1	0	0	16	0	3
Option #3B	0	0	1	0	3.1	0	0	16	0	
Option #8A	0	0	1	0	3.1	0	0	16	0	
Option #8B	0	0	1	0	3.1	0	0	16	0	

### Preferred Option Performance– N-1-1 Analysis (P6 Events)

- None of the contingencies lead to divergent power flow solutions
  - Load shed levels are limited to 16 MW to mitigate the 69kV overloads
- All preferred options meet ERCOT/NERC TPL-001-4 criteria from reliability standpoint



## Additional Analysis Preferred Options – Panhandle Generation Sensitivity

---

- All Antelope generation (Elk 1, Elk 2 and Elk 3) were dispatched at full output during sensitivity studies
  - Elk 1: 359 MW
  - Elk 2: 197 MW
  - Elk 3: 197 MW
- A-1+N-1 & G-1+N-1 assessments were performed as a part of the sensitivity studies
  - Mckenzie unit (78MW) was still considered as the most severe G-1 outage within LP&L facilities
- With Elk units dispatched at full output, none of LP&L existing facilities were observed to be loaded above 85% for all four (4) preferred options
  - 345kV partial loop around LP&L observed to effectively distribute power under these conditions
- Panhandle generation including Antelope generation expected to have better deliverability to ERCOT system in the presence of the partial loop

## Additional Analysis Preferred Options – Dynamic Assessment

- ERCOT Dynamic Working Group (DWG) Future Year 2021 Flat Start Dataset utilized for the dynamic analysis
- LP&L system was added to the ERCOT dataset
  - Separate dynamic dataset for each of the four (4) preferred options
  - LP&L system load was modelled to represent high load growth scenario (~ 593 MW)
- Dynamic data associated with LP&L system generation was taken from SPP models
  - Data includes models for generator, excitation system and governor system
- 'CLOD model' was utilized to model the dynamic nature of LP&L system loads
  - Customer type (residential, commercial etc) at each substation was provided by LP&L
  - Typical parameters were assumed for load mix (i.e. % of large motors, % small motors etc)
- All generation resources meeting section 6.9 requirements of ERCOT planning guide incrementally modeled in the case
  - Antelope gas generation units kept offline for the dynamic analysis
  - Wind generation resources in the vicinity of Lubbock dispatched at 20%

## Additional Analysis Preferred Options – Dynamic Assessment

- Following incremental updates made to the dynamic datasets in line with ERCOT Panhandle Transfer Capability Assessment dated September 2015
  - Addition of 2<sup>nd</sup> circuit on the Panhandle loop
  - Addition of 150 MVA of synchronous condensers at Sharyland's 345 kV Alibates and Tule Canyon stations
- P1-P7 category events developed in accordance with NERC transmission planning standard TPL-001-4 and ERCOT Planning Guide
  - 3-Phase fault based events studied for worst case scenario
  - G-1 conditions around loss of LP&L Holly & Mackenzie units evaluated for P3 events
  - Outage of 345 kV/115 kV transformers at North, Wadsworth and New Oliver stations included as part of first contingency for A-1+N-1 events
  - P1 and P7 events are included as part of second contingency for both G-1+N-1 & A-1+N-1 events
  - Per discussion with LP&L, no non-redundant protection schemes by the time of ERCOT integration on their facilities – P5 events not applicable
- ERCOT Planning Guide & NERC TPL-001-4 performance criteria/guidelines were utilized to assess the dynamic performance of the preferred options

# Dynamic Analysis for Preferred Options

## Dynamic Simulation Results

- The study area was observed to be stable for all simulated events across all options studied
  - The rotor angle stability of the LP&L system and ERCOT system was maintained
  - The transient voltage recovery response of the study area was acceptable and in-line with ERCOT Planning Guide for P1-P7 events studied
  - No voltage collapse or system wide instability issues were observed
  - No incremental generation trips were observed other than the units that were tripped as part of the dynamic event
    - Only exception is breaker failure at North/McKenzie station – CCT for McKenzie generation will need to be updated as part of ERCOT integration

	<b>P1/P2 Events</b>	<b>P3 Events</b>	<b>P4 Events</b>	<b>P6 Events</b>	<b>P7 events</b>
<b>Option#3-a</b>	Stable	Stable	Stable*	Stable	Stable
<b>Option#3-b</b>	Stable	Stable	Stable*	Stable	Stable
<b>Option#8-a</b>	Stable	Stable	Stable*	Stable	Stable
<b>Option#8-b</b>	Stable	Stable	Stable*	Stable	Stable

## Additional Analysis Preferred Options – Economic Assessment

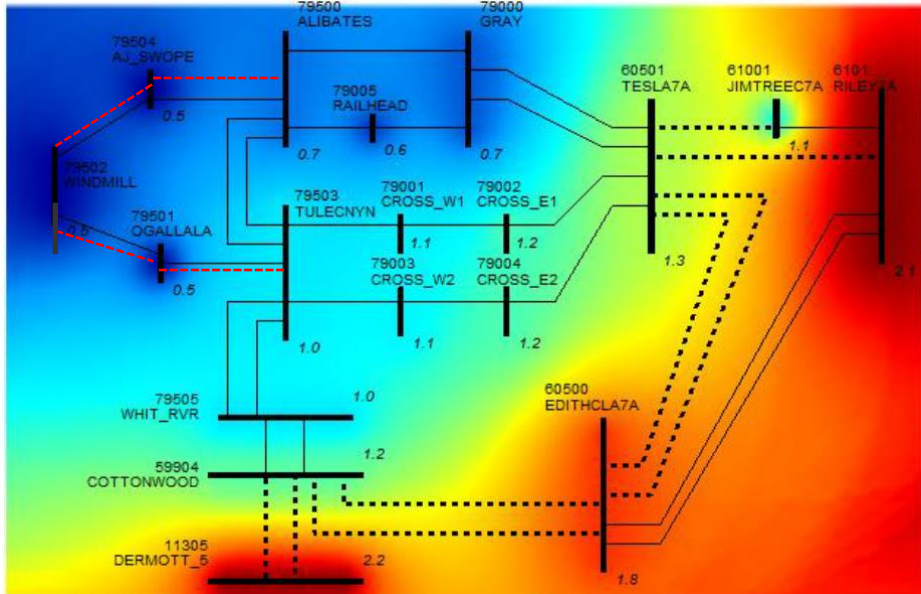
- Hourly production-cost based economic analysis performed for the preferred options
- Key objective of the economic analysis to quantify the relative annual production cost savings associated with the preferred options
  - Specific focus on quantifying benefit of LP&L on Panhandle wind deliverability
    - Panhandle wind deliverability benefited in terms of two aspects by virtue of LP&L integration
    - LP&L load “local load” for Panhandle by virtue of the integration
    - WSCR/Voltage stability benefits further increase Panhandle export capability
- Study Scenario
  - Base Case – No LP&L Integration, 2<sup>nd</sup> circuit on Panhandle loop & SCs (and their impact) included
  - Change Cases – Base Case + LP&L Load + LP&L Integration Option
- Future generation unit additions limited to those meeting Section 6.9 requirements of ERCOT Planning Guide

## Additional Analysis Preferred Options – Economic Assessment

	STUDY YEAR 2021
	DNV GL Assumptions
Installed Capacity, Thermal/Hydro/Nuclear/Solar	65,248.24
Switchable Capacity, MW	3,667.00
less: Switchable Capacity Unavailable to ERCOT, MW	(524.00)
Available Mothballed Capacity, MW	1,875.00
Capacity from Private Use Networks	4,561.52
Non-Coastal Wind, Peak Average Capacity Contribution (12%)	1,331.28
Coastal Wind, Peak Average Capacity Contribution (56%)	940.24
RMR Capacity to be under Contract	0.00
<b>Operational Generation Capacity, MW</b>	<b>77,099.28</b>
Capacity Contribution - Non-Synchronous Ties, MW	516.7
Planned Resources (not wind) meeting Section 6.9 req. of ERCOT PG	2,916.40
Planned Non-Coastal Wind meeting Section 6.9 req. of ERCOT PG, Contribution (12%)	766.32
Planned Coastal Wind meeting Section 6.9 req. of ERCOT PG, Contribution (56%)	929.04
<b>Total Capacity, MW</b>	<b>82,227.74</b>
<b>Firm Peak Load, MW</b>	<b>72,180.00</b>
<b>Reserve Margin</b>	<b>14%</b>

### Economic Modeling Assumptions Summary, 2021

# Additional Analysis Preferred Options – Economic Assessment



## Panhandle Transmission Interface

(Source: Panhandle Transfer Capability Analysis, ERCOT, September 2015)

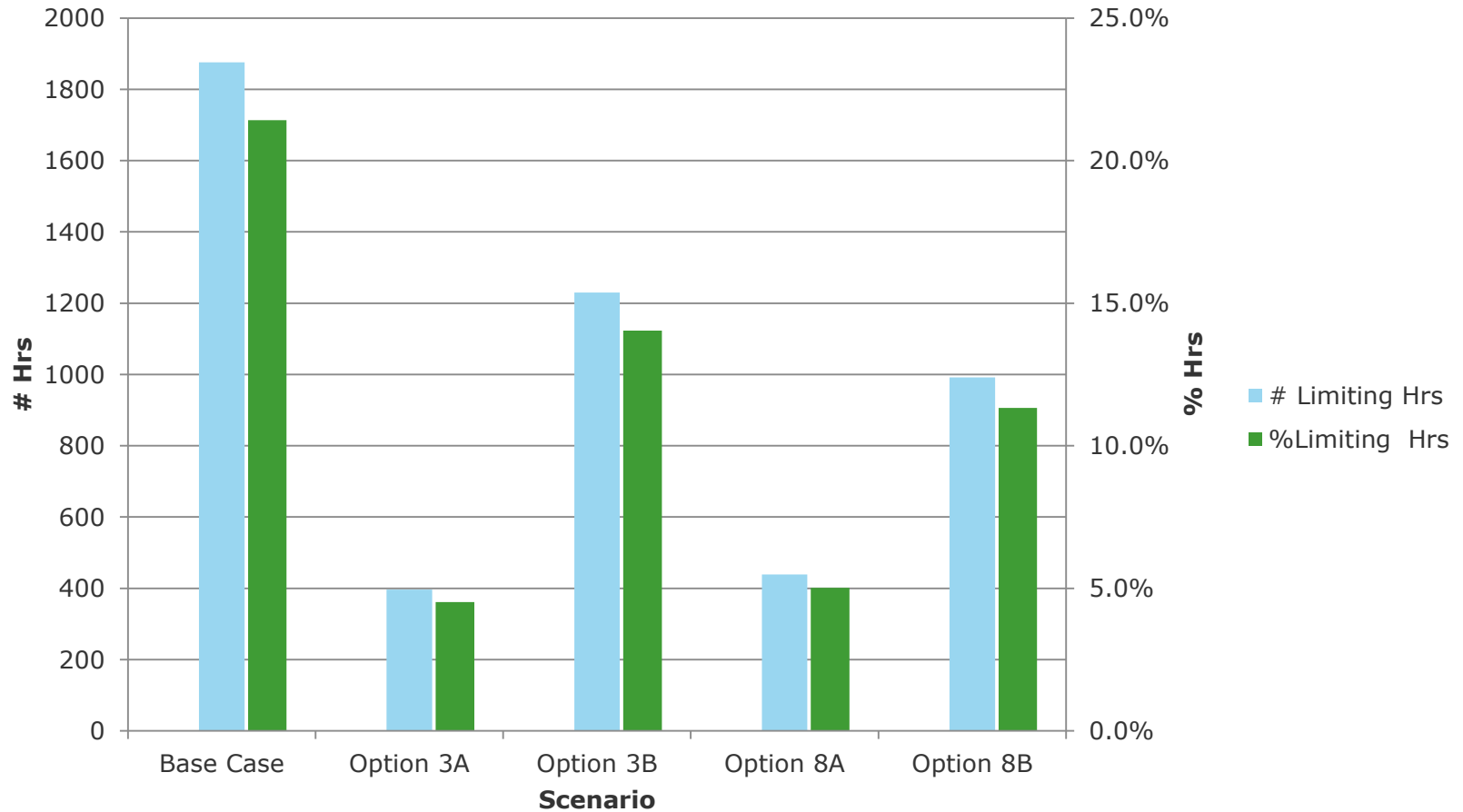
## Panhandle Export Limits – Study Scenarios, Economic Assessment

Option#	Voltage Stability Limit	System Strength Limit		Minimum of WSCR & VS Limit (MW)	Maximum Operational Limit (90% of limit) (MW)
	Planning Studies (MW)	WSCR with 4302MW	Generation Capacity in MW for WSCR = 1.5		
Base Case	4044	1.35	3872	3872	3484.8
3A	>4500	1.55	4474	4474	4026.6
3B	>4500	1.45	4152	4152	3736.8
8A	>4500	1.54	4431	4431	3987.9
8B	>4500	1.44	4130	4130	3717



# Additional Analysis Preferred Options – Economic Assessment

## Panhandle Interface Constraint Analysis



**Significant Reduction in Panhandle Export Constraints for Scenarios 3 and 8**

## Additional Analysis Preferred Options – Economic Assessment

- **Relative production cost savings** utilized to evaluate potential economic benefits provided by each option
- Options 3A and 8A exhibit comparable performance from a production cost savings standpoint
- Option 8B depicts ~\$5M/year APC savings in comparison to Option 3B albeit at a higher capital cost
- Economics of 345kV Ogallala – Abernathy segment are observed to be better justified in Option 3 when compared to Option 8
  - APC/Capital Cost of 9.55% for Ogallala-Abernathy line in Option 3 & 4.43% in Option 8
  - ERCOT economic criteria requirement is 15% or more

### Relative Annual Production Cost Savings Evaluation

Description	Option 3A	Option 3B	Option 8A	Option 8B
Relative APC Savings (\$M)	9.55	0.00	9.25	4.82
APC Savings Ogallala - Abernathy line (\$M)	9.55		4.44	

## Cost-Benefit Assessment – Preferred Options

- Cost-Benefit (C/B) assessment performed to quantify benefits accrued by LP&L integration options
  - Primarily accounts for known and quantifiable benefits – avoided costs in terms of transmission upgrades that will be eliminated by LP&L integration
  - Any other benefits afforded by LP&L i.e. two (2) 50 MVA generation units expected to be retired in the future that can potentially serve as Synchronous Condensers
  - Other benefits such as SSR and APC savings not directly accounted for in the C/B assessment
  - C/B assessment limited to capital cost impacts on the integration options

Cost Description	Option 3A	Option 3B	Option 8A	Option 8B
Gross Capital Cost of Integration Options (\$M)	\$429.00	\$330.00	\$476.00	\$376.00
Avoided Costs by virtue of LP&L Integration				
SC Cost Replaced by LP&L Integration (\$M)	\$83.20	\$51.40	\$83.20	\$51.40
Additional SC Benefits by virtue of LP&L Integration				
100 MVA SC ERCOT Cost (\$M)	\$21.33	\$21.33	\$21.33	\$21.33
LP&L Cost of re-furbishing two (2) 50 MVA generation units as SCs (\$M)	\$12.00	\$12.00	\$12.00	\$12.00
Net Benefit - Refurbished SCs (\$M)	\$9.33	\$9.33	\$9.33	\$9.33
Net Cost of Integration Options (\$M)				
<b>Net Cost of Integration Options (\$M)</b>	<b>\$336.47</b>	<b>\$269.27</b>	<b>\$383.47</b>	<b>\$315.27</b>

## Recommendations

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- Based on analysis and results presented, following recommendations for LP&L Integration to ERCOT
  - Option 3B – **1<sup>st</sup> Recommended Option** with potential to phase in Ogallala – Abernathy line in the future (Option 3A)
    - Ogallala – Abernathy line justification expected to be based on ERCOT reliability/economic criteria
  - Option 8B – **2<sup>nd</sup> Recommended Option** with potential to phase in Ogallala – Abernathy line in the future (Option 8A)
    - Ogallala – Abernathy line justification expected to be based on ERCOT reliability/economic criteria
- Final report to be submitted to ERCOT for RPG stakeholder review and comments

# Thank You

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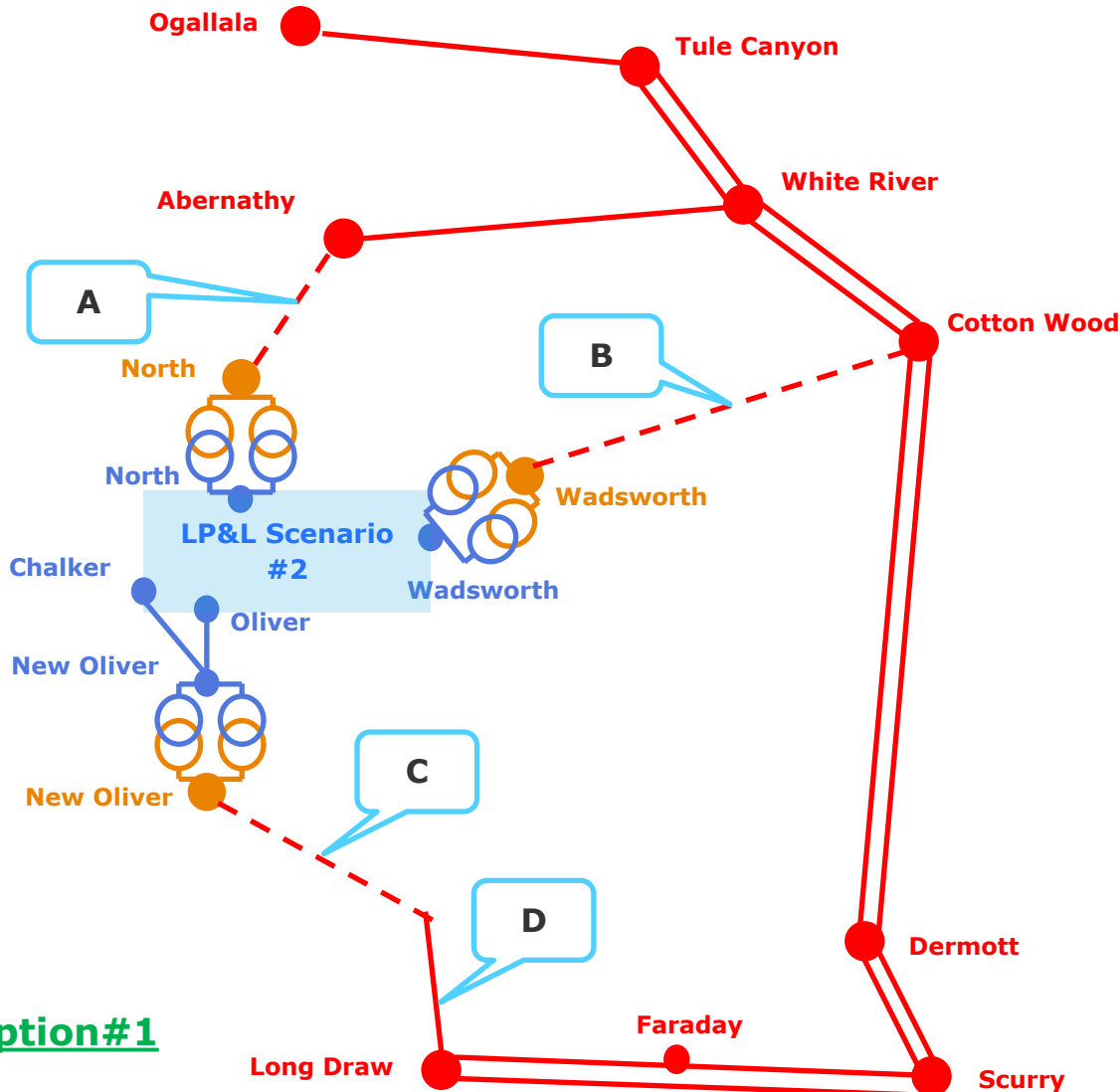
**Ph: 214-678-1197**

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# LP&L Integration Options – One-Line Schematics

# Three (3) Sources to LP&L

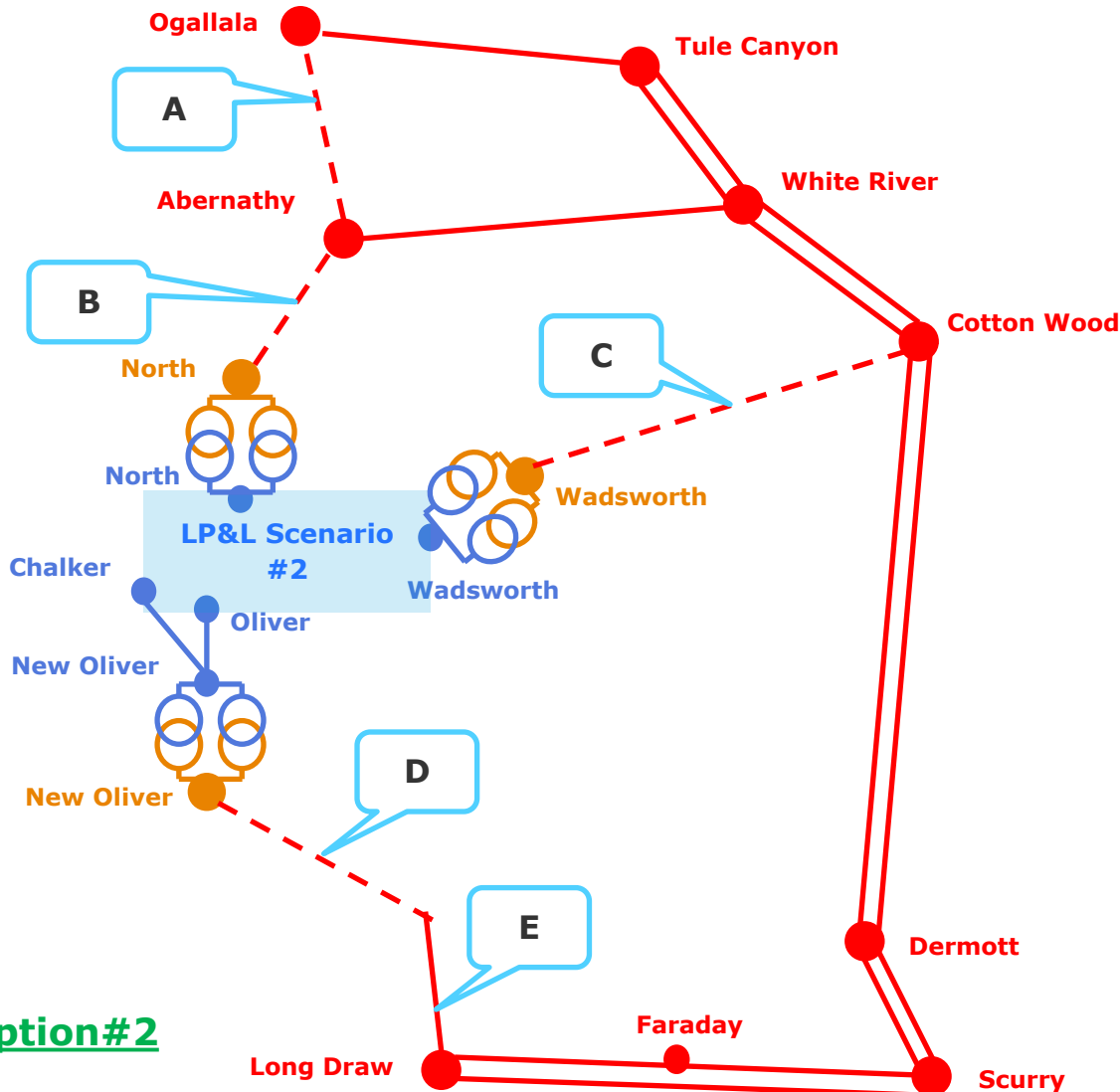


- **Option#1:**
- **A** = 345kV line from Abernathy to LP&L North Sub
- **B** = 345kV line from Cotton Wood to LP&L Wadsworth
- **C** = Extend 345kV Grassland extension to New Oliver
- **D** = Existing 345kV line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

**Option#1**



# Three (3) Sources to LP&L

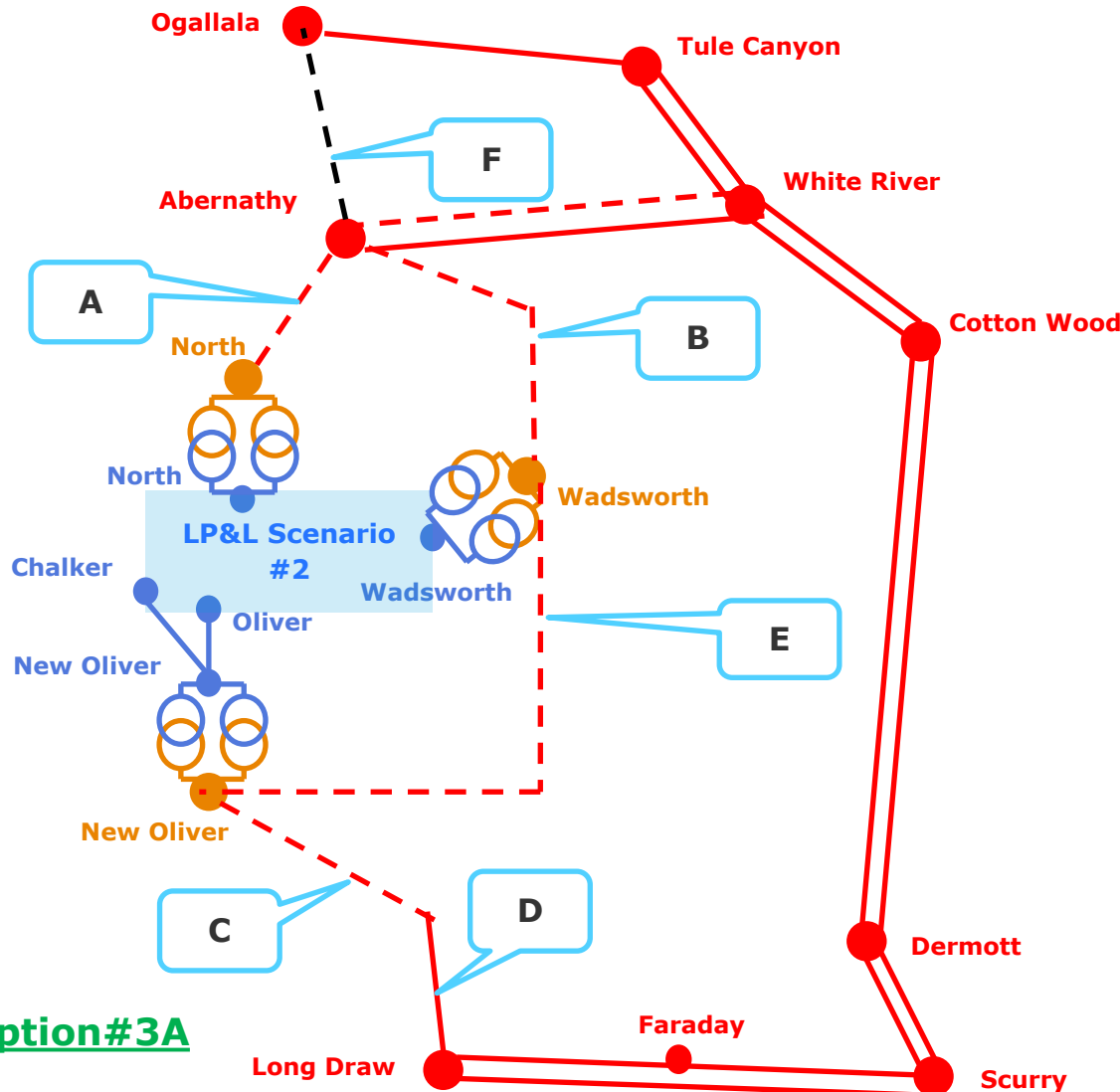


## Option#2:

- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North Sub
- **C** = 345kV line from Cotton Wood to LP&L Wadsworth
- **D** = Extend 345kV Grassland extension to New Oliver
- **E** = Existing 345kV line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## Option#2

# Three (3) Sources to LP&L

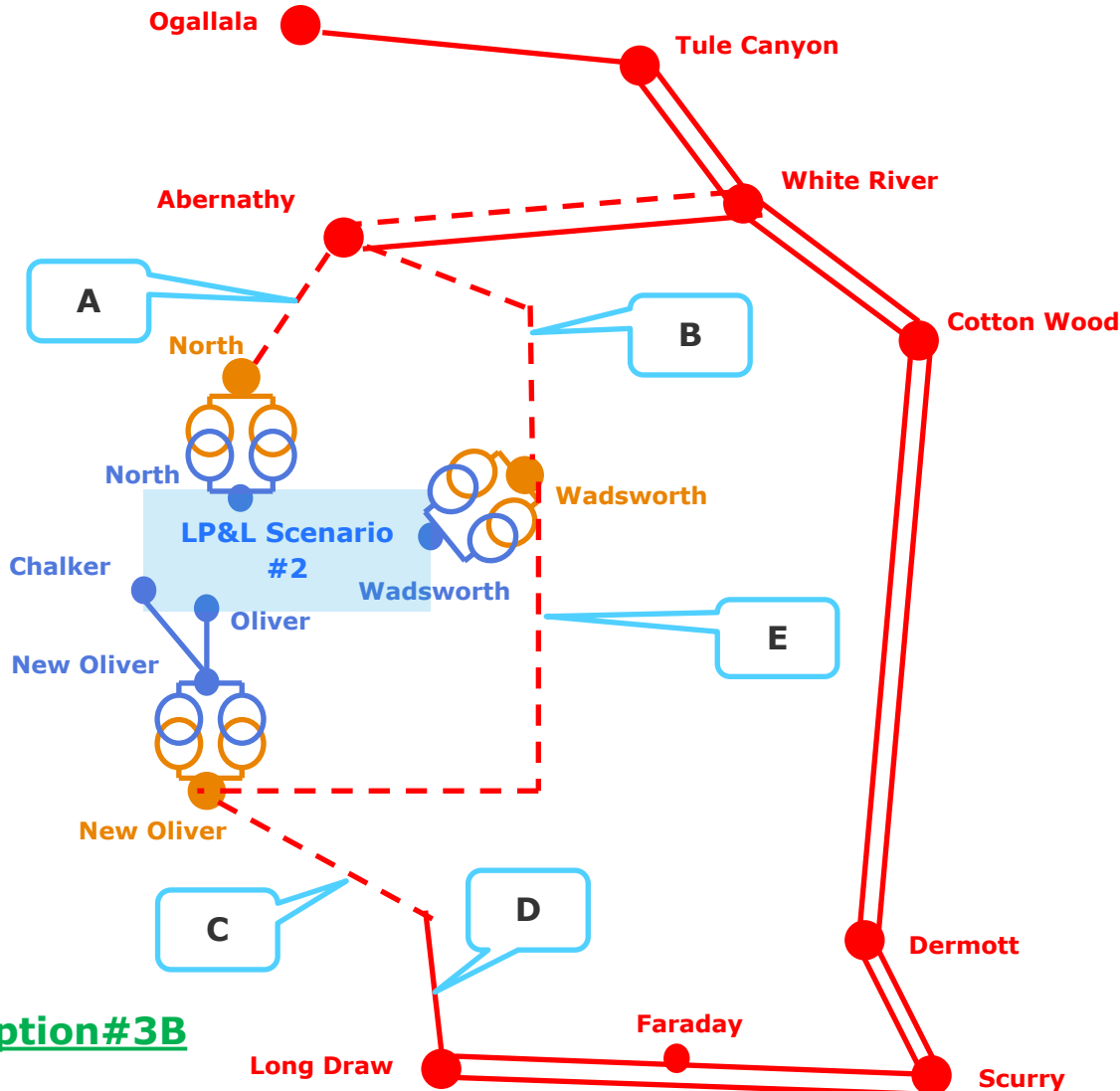


## **Option#3A (Preferred):**

- **A** = 345kV line from Abernathy to LP&L North Sub
- **B** = 345kV line from Abernathy to LP&L Wadsworth
- **C** = Extend 345kV Grassland extension to New Oliver
- **D** = Existing 345kV line
- **E** = 345kV line LP&L Wadsworth to New Oliver
- **F** = 345kV line from Ogallala – Abernathy
- Add a 2<sup>nd</sup> circuit on the existing Abernathy – White River line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

**Option#3A**

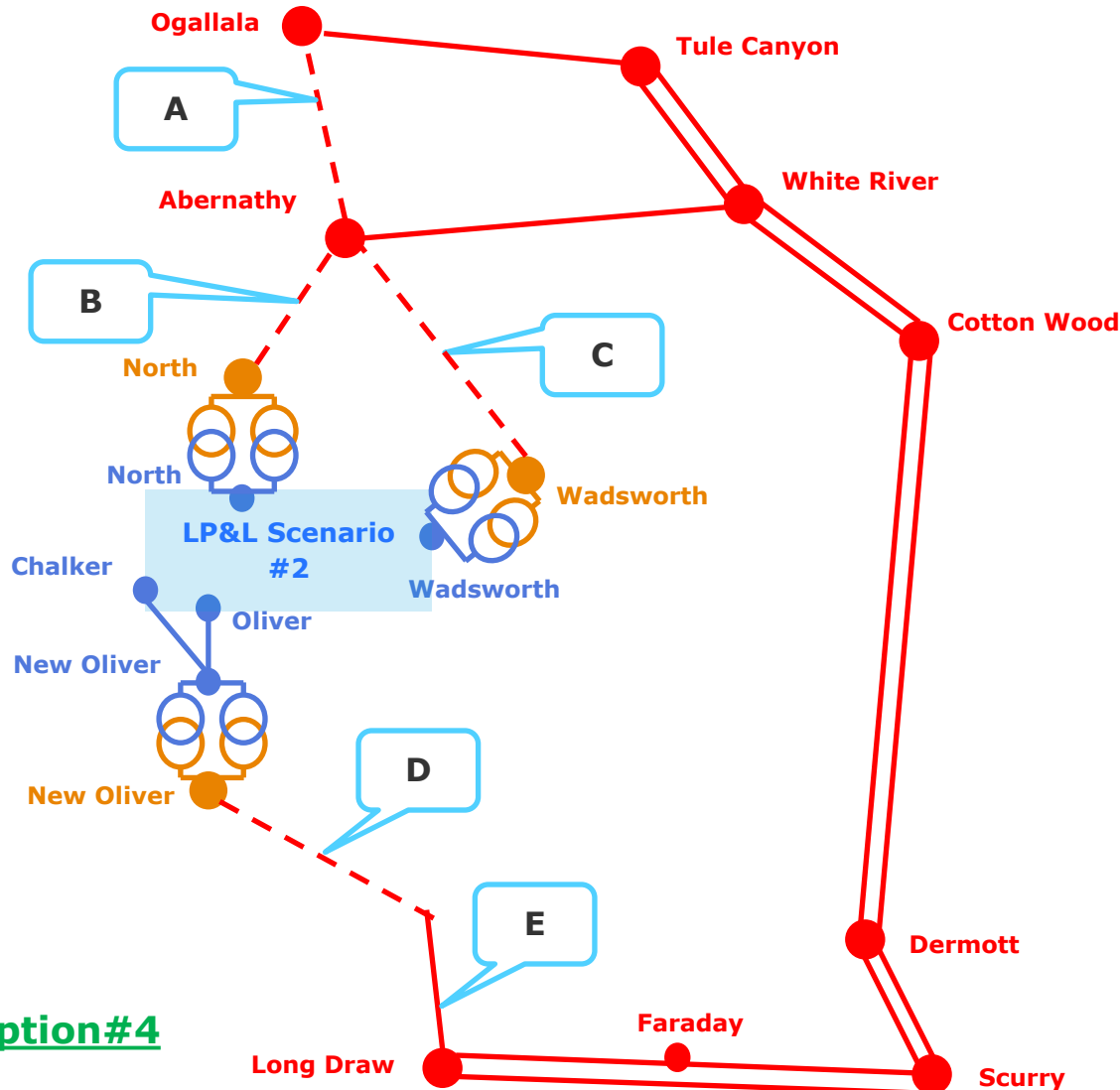
# Evaluation of Modified Options #3 and #8



- **Option#3B (Preferred):**
- **A** = 345kV line from Abernathy to LP&L North Sub
- **B** = 345kV line from Abernathy to LP&L Wadsworth
- **C** = Extend 345kV Grassland extension to New Oliver
- **D** = Existing 345kV line
- **E** = 345kV line LP&L Wadsworth to New Oliver
- Add a 2<sup>nd</sup> circuit on the existing Abernathy – White River line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

**Option#3B**

# Three (3) Sources to LP&L

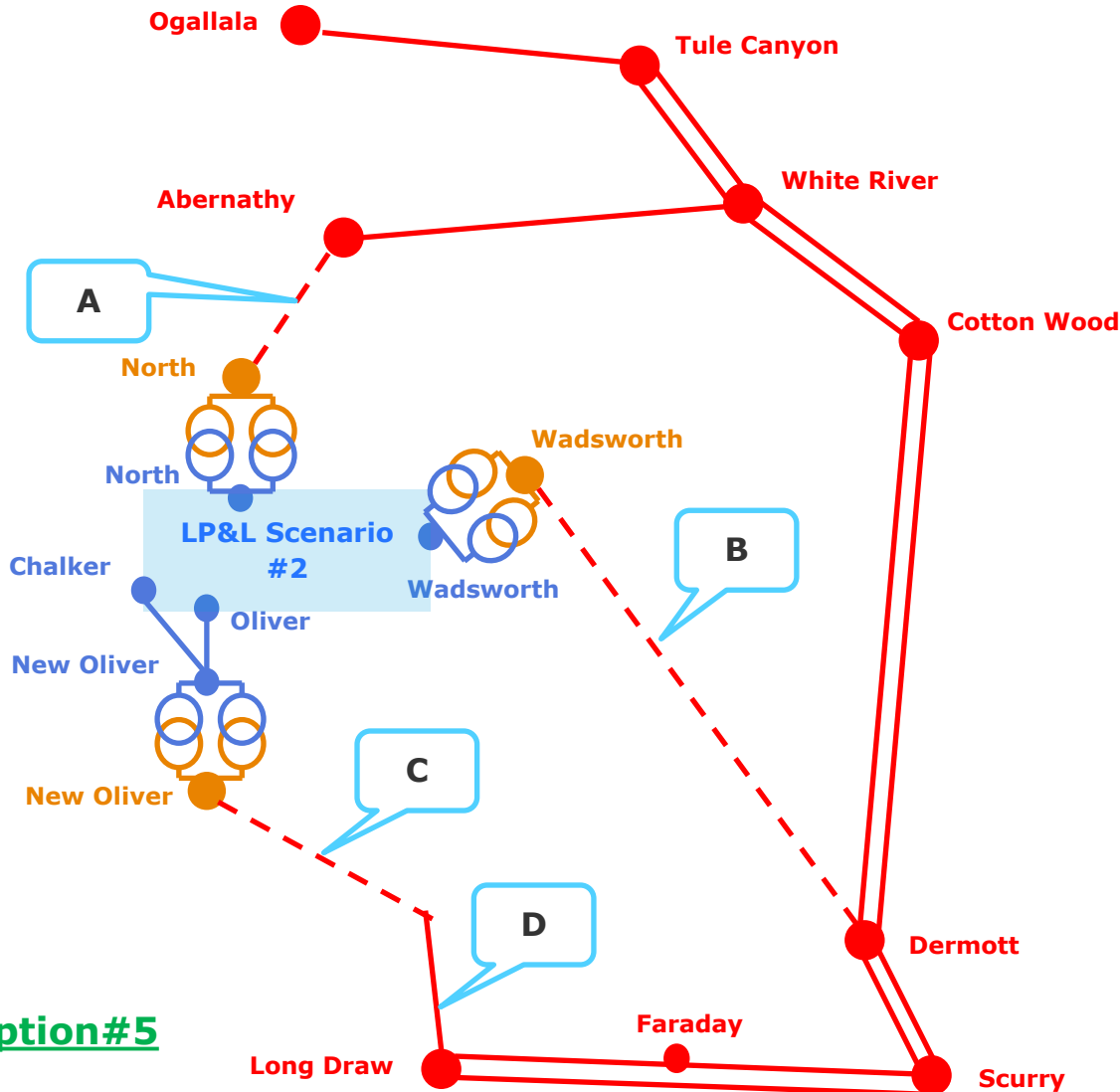


## **Option#4:**

- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North Sub
- **C** = 345kV line from Abernathy to LP&L Wadsworth
- **D** = Extend 345kV Grassland extension to New Oliver
- **E** = Existing 345kV line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## **Option#4**

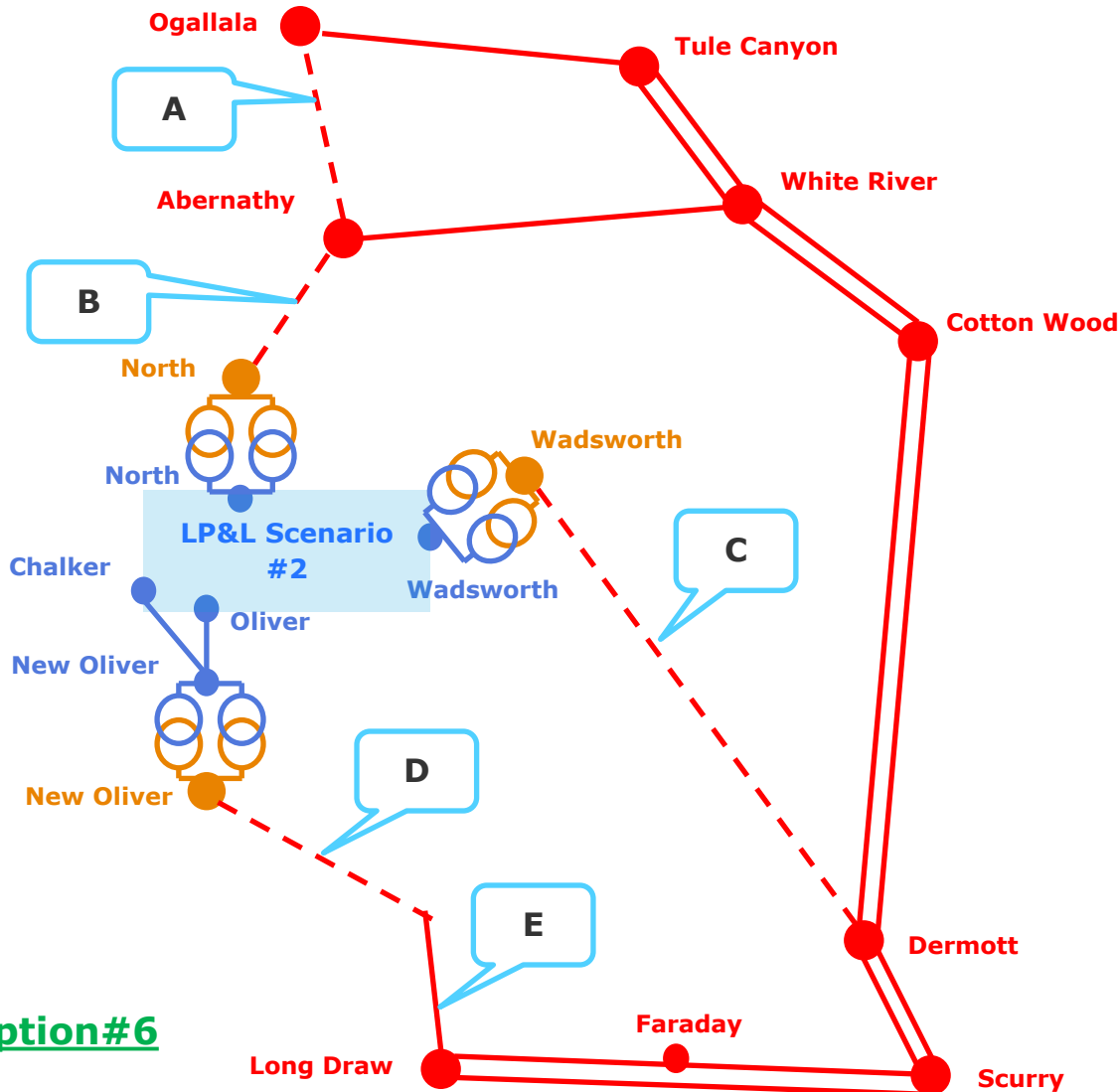
# Three (3) Sources to LP&L



- **Option#5:**
- **A** = 345kV line from Abernathy to LP&L North Sub
- **B** = 345kV line from Dermott to LP&L Wadsworth
- **C** = Extend 345kV Grassland extension to New Oliver
- **D** = Existing 345kV line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## Option#5

# Three (3) Sources to LP&L

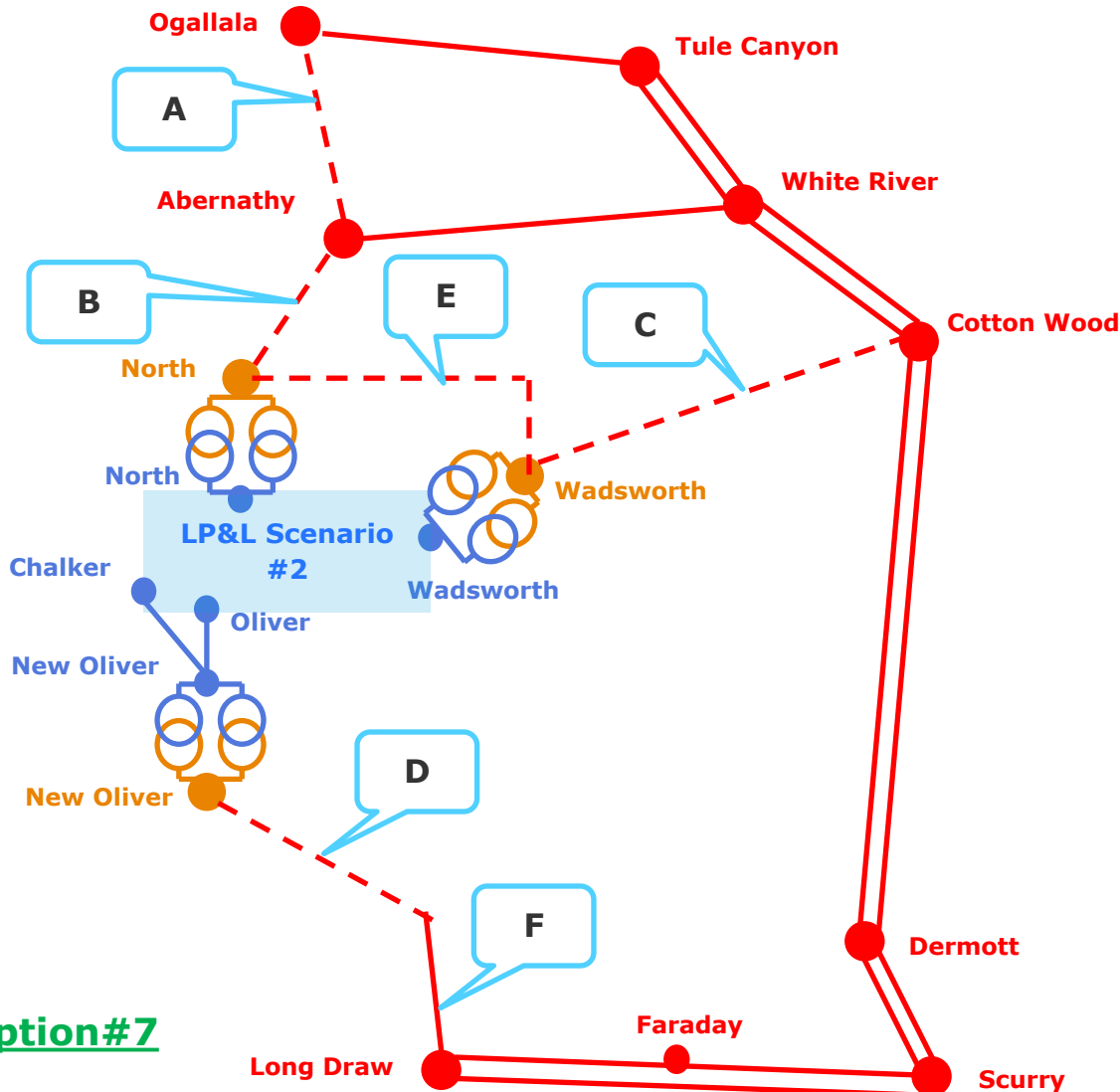


## **Option#6:**

- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North Sub
- **C** = 345kV line from Dermott to LP&L Wadsworth
- **D** = Extend 345kV Grassland extension to New Oliver
- **E** = Existing 345kV line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## **Option#6**

# Three (3) Sources to LP&L



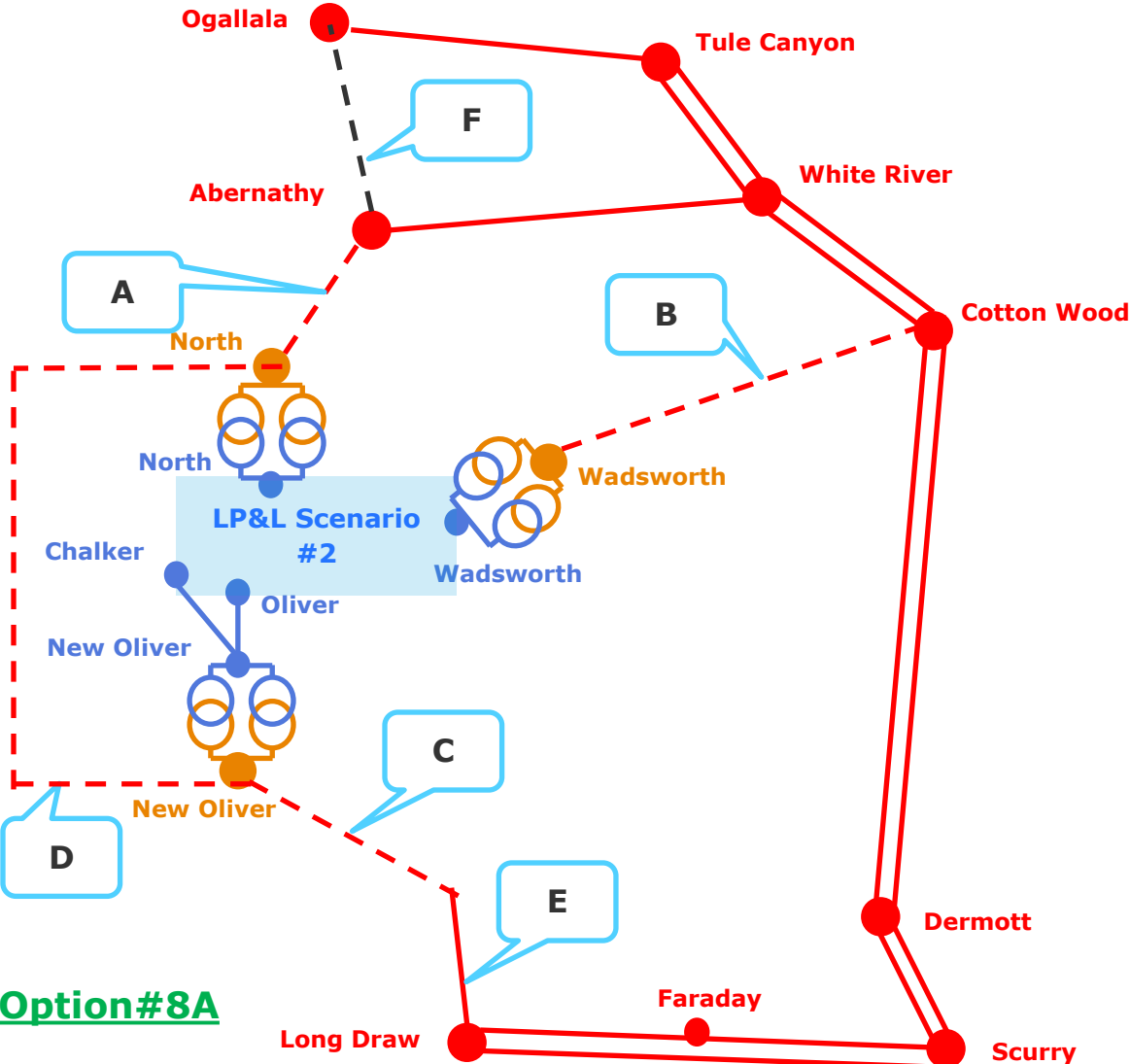
## Option#7:

- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North Sub
- **C** = 345kV line from Cotton Wood to LP&L Wadsworth
- **D** = Extend 345kV Grassland extension to New Oliver
- **E** = 345kV line LP&L North to LP&L Wadsworth
- **F** = Existing 345kV line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## Option#7



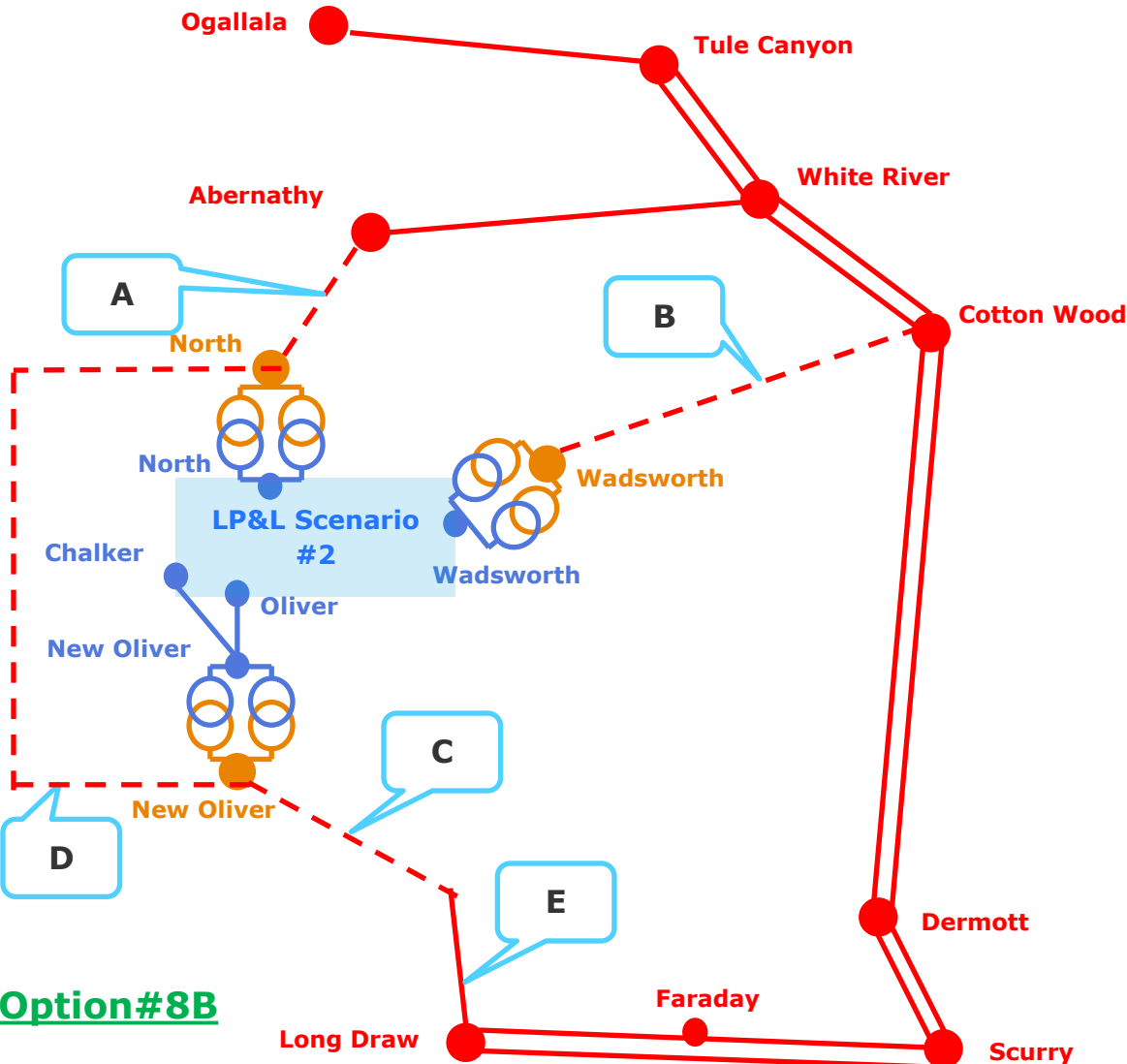
# Evaluation of Modified Options #3 and #8



- **Option#8A (Preferred):**
- **A** = 345kV line from Abernathy to LP&L North Sub
- **B** = 345kV line from Cotton Wood to LP&L Wadsworth
- **C** = Extend 345kV Grassland extension to New Oliver
- **D** = 345kV line LP&L North to New Oliver
- **E** = Existing 345kV line
- **F** = 345kV line from Ogallala to Abernathy
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

**Option#8A**

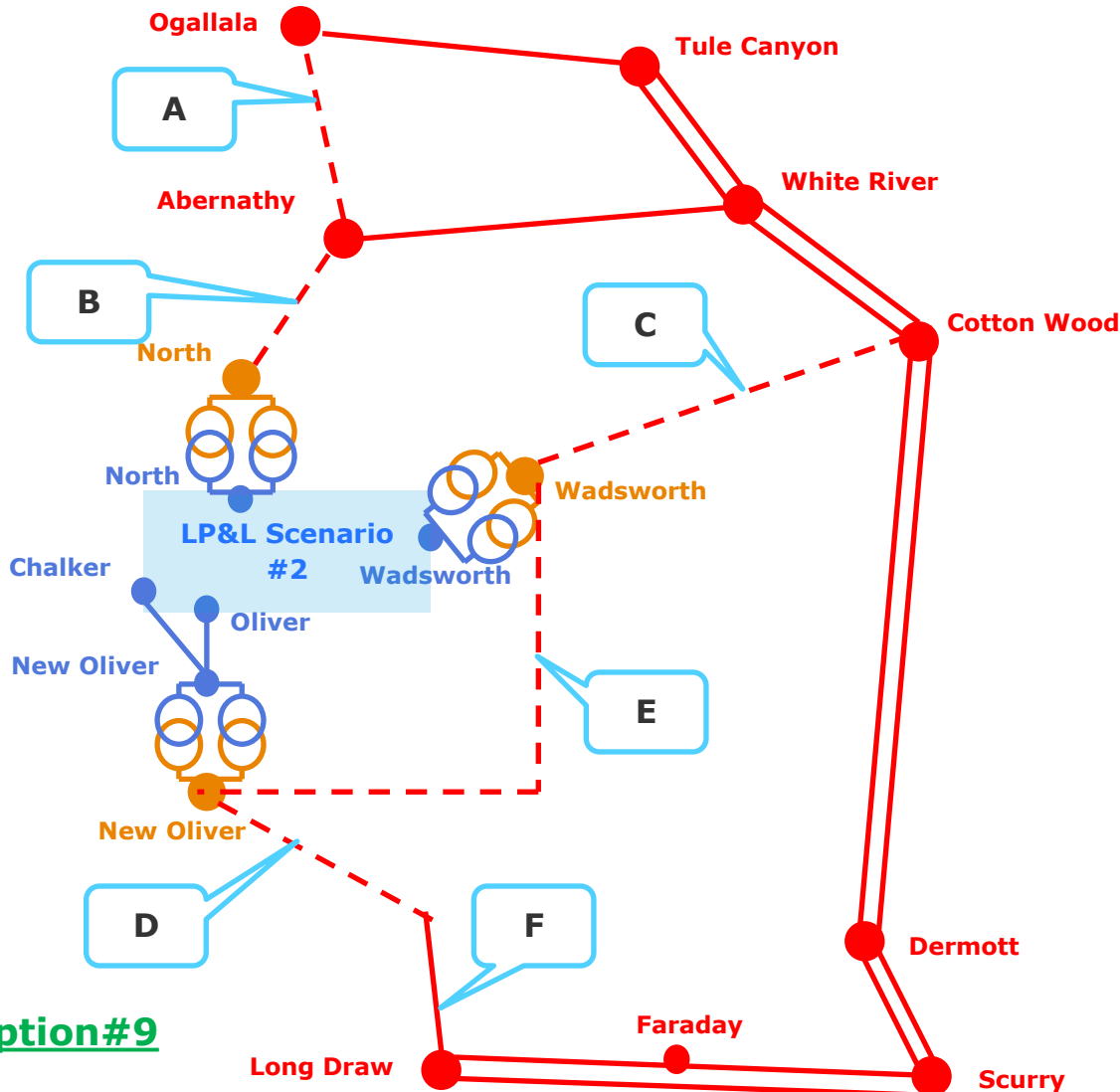
# Three (3) Sources to LP&L



- **Option#8B (Preferred):**
- **A** = 345kV line from Abernathy to LP&L North Sub
- **B** = 345kV line from Cotton Wood to LP&L Wadsworth
- **C** = Extend 345kV Grassland extension to New Oliver
- **D** = 345kV line LP&L North to New Oliver
- **E** = Existing 345kV line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## Option#8B

# Three (3) Sources to LP&L

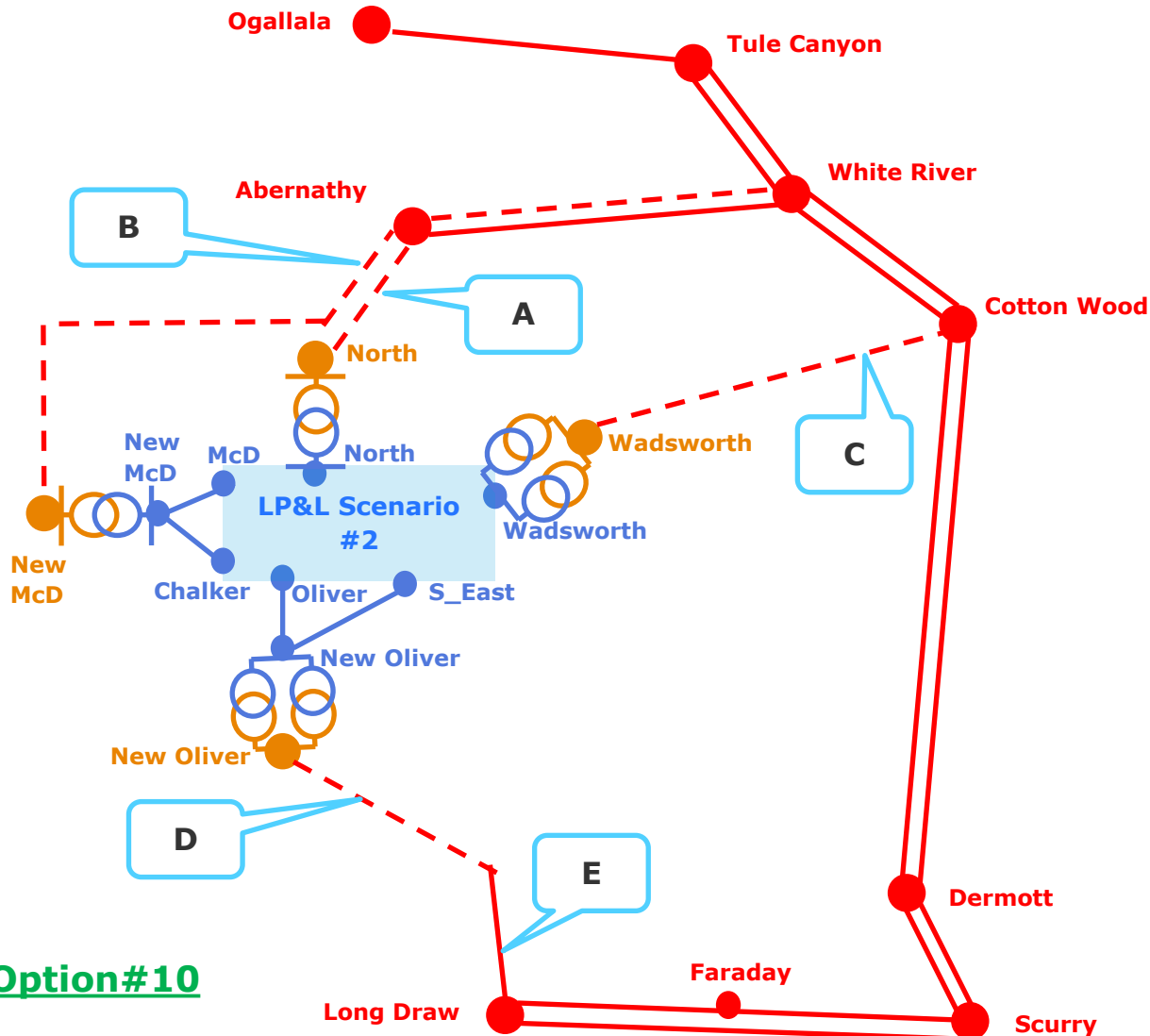


## Option#9:

- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North Sub
- **C** = 345kV line from Cotton Wood to LP&L Wadsworth
- **D** = Extend 345kV Grassland extension to New Oliver
- **E** = 345kV line LP&L Wadsworth to New Oliver
- **F** = Existing 345kV line
- Two (2) 345/115kV Transformers at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## Option#9

# Four (4) Sources to LP&L

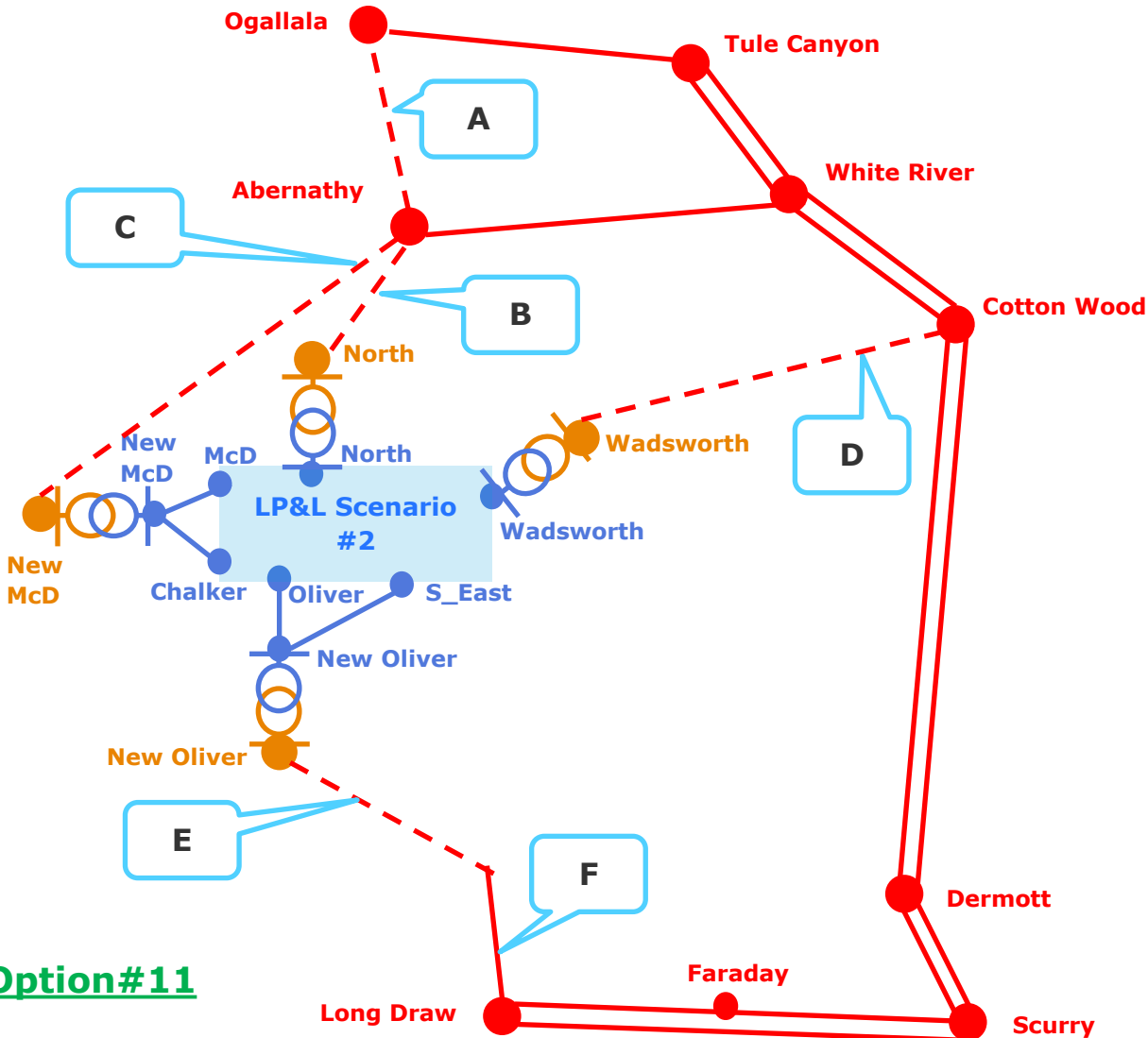


## Option#10:

- **A** = 345kV line from Abernathy to LP&L North
- **B** = 345kV line from Abernathy to New McDonald
- **Lines A and B share same tower up to North**
- **C** = 345kV line from Cotton Wood to LP&L Wadsworth
- **D** = Extend 345kV Grassland extension to New Oliver
- **E** = Existing 345kV line
- Add a 2<sup>nd</sup> circuit on the existing White River - Abernathy
- Two 345/115kV Transformers at New Oliver and Wadsworth
- Two (2) 115kV lines from New Oliver to existing Oliver and South East

**Option#10**

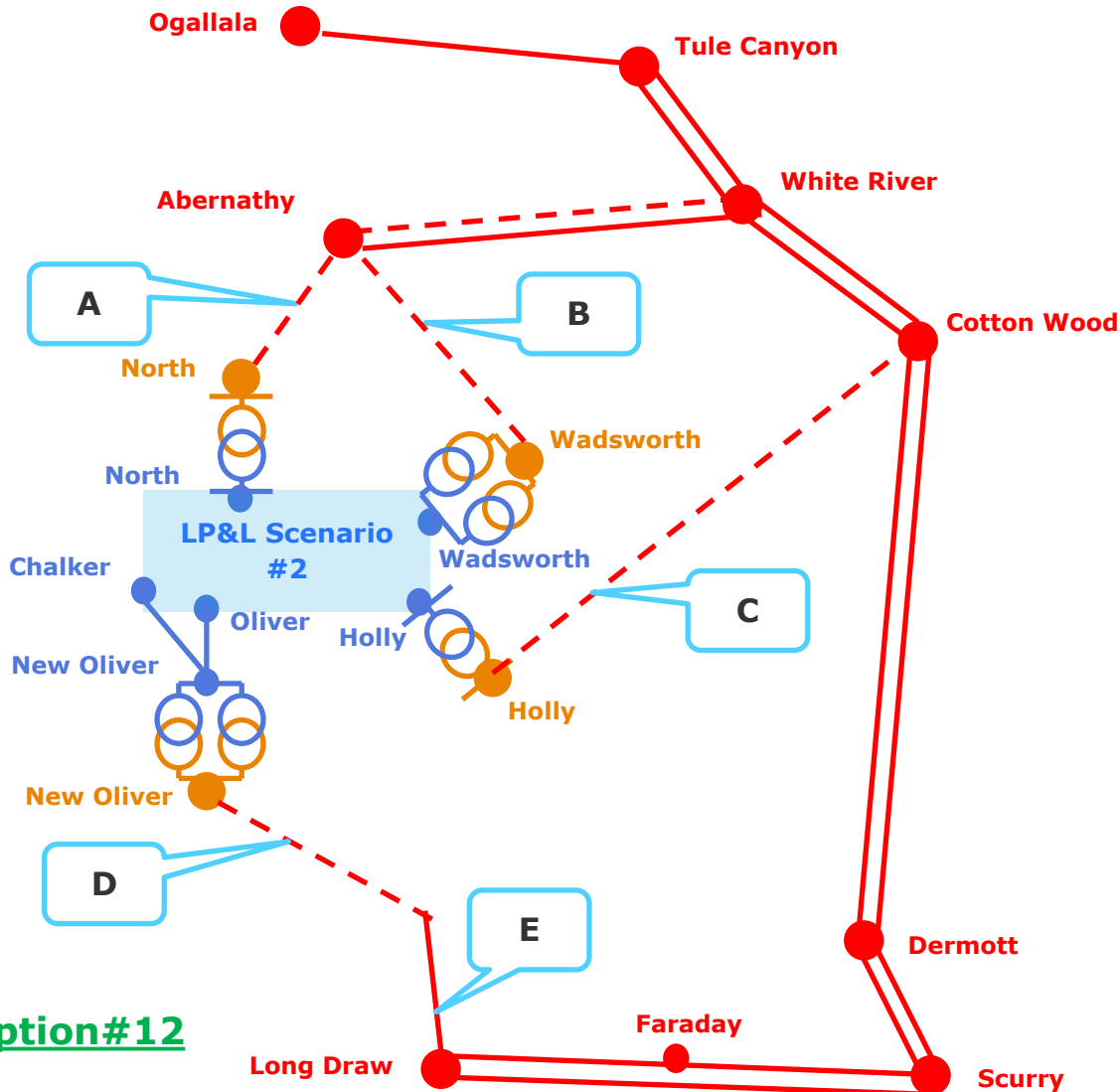
# Four (4) Sources to LP&L



- **Option#11:**
- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North
- **C** = 345kV line from Abernathy to New McDonald
- **D** = 345kV line from Cotton Wood to LP&L Wadsworth
- **E** = Extend 345kV Grassland extension to New Oliver
- **F** = Existing 345kV line
- One 345/115kV Transformer at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and South East
- Two (2) 115kV lines from New McDonald to existing McDonald and Chalker

## Option#11

# Four (4) Sources to LP&L

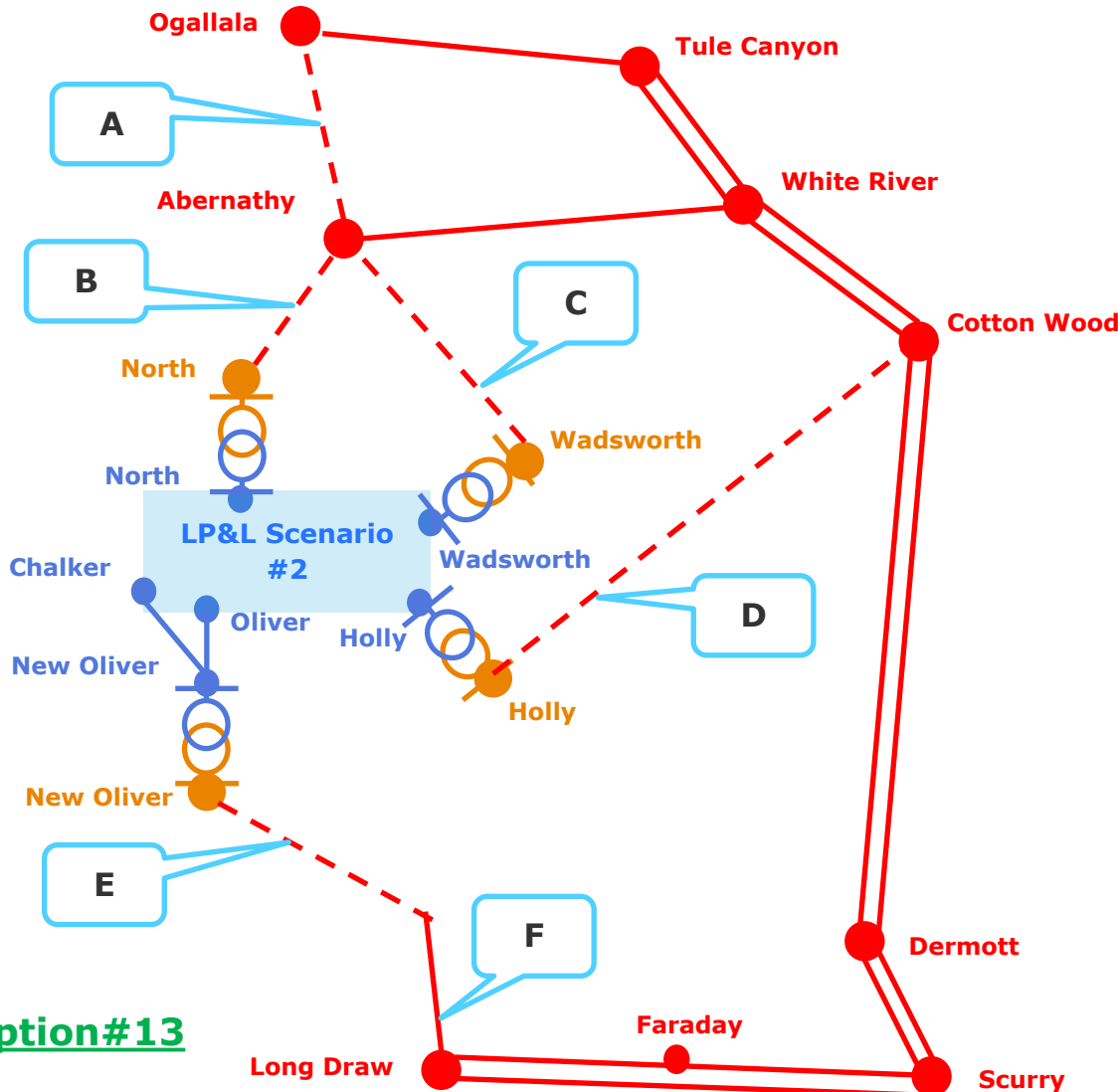


## Option#12:

- **A** = 345kV line from Abernathy to LP&L North
- **B** = 345kV line from Abernathy to LP&L Wadsworth
- **C** = 345kV line from Cotton Wood to LP&L Holly
- **D** = Extend 345kV Grassland extension to New Oliver
- **E** = Existing 345kV line
- Add a 2<sup>nd</sup> circuit on the existing White River - Abernathy
- Two (2) 345/115kV Transformer at Wadsworth and New Oliver
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## Option#12

# Four (4) Sources to LP&L

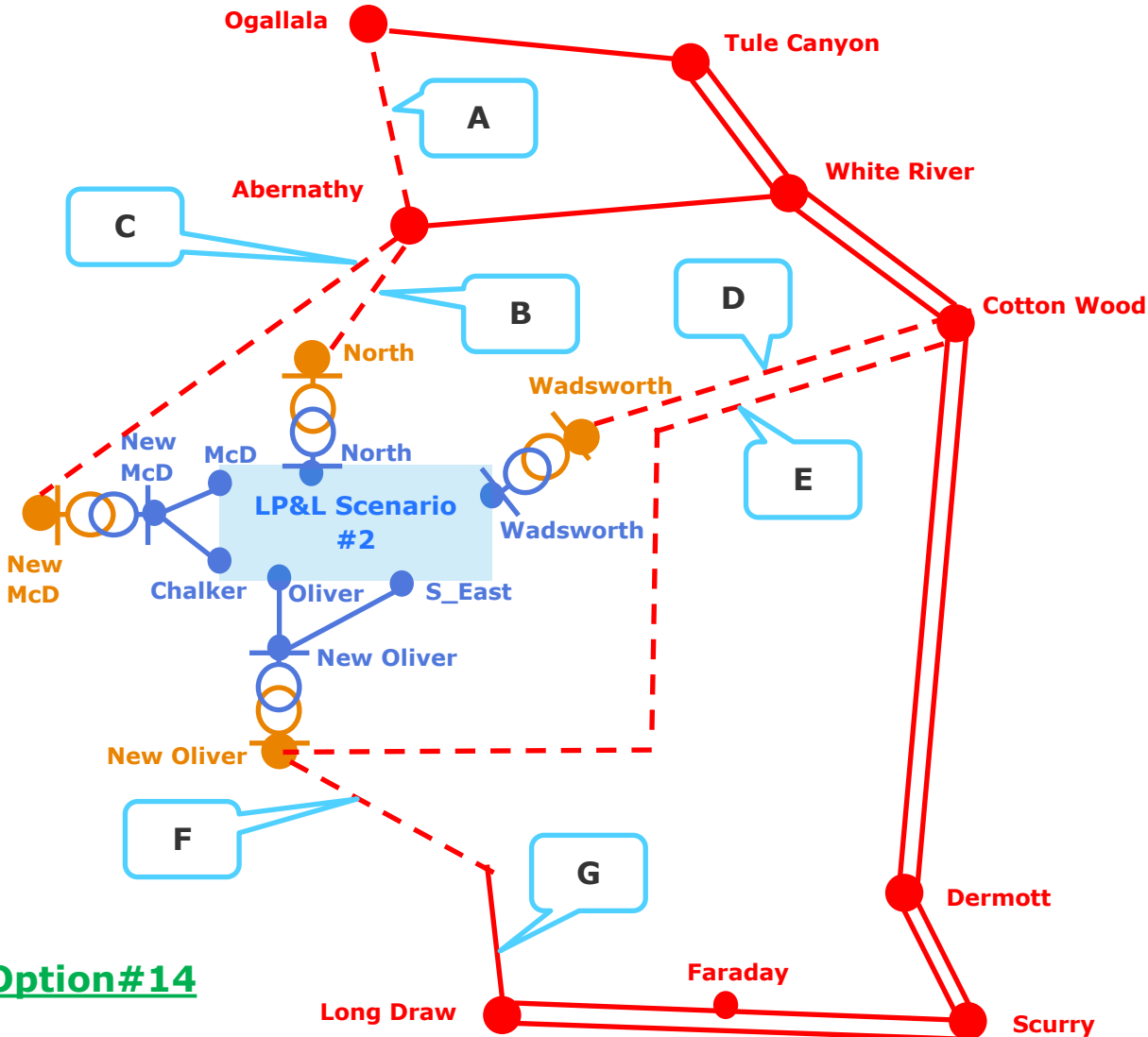


- **Option#13:**
- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North
- **C** = 345kV line from Abernathy to LP&L Wadsworth
- **D** = 345kV line from Cotton Wood to LP&L Holly
- **E** = Extend 345kV Grassland extension to New Oliver
- **F** = Existing 345kV line
- One (1) 345/115kV at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## Option#13



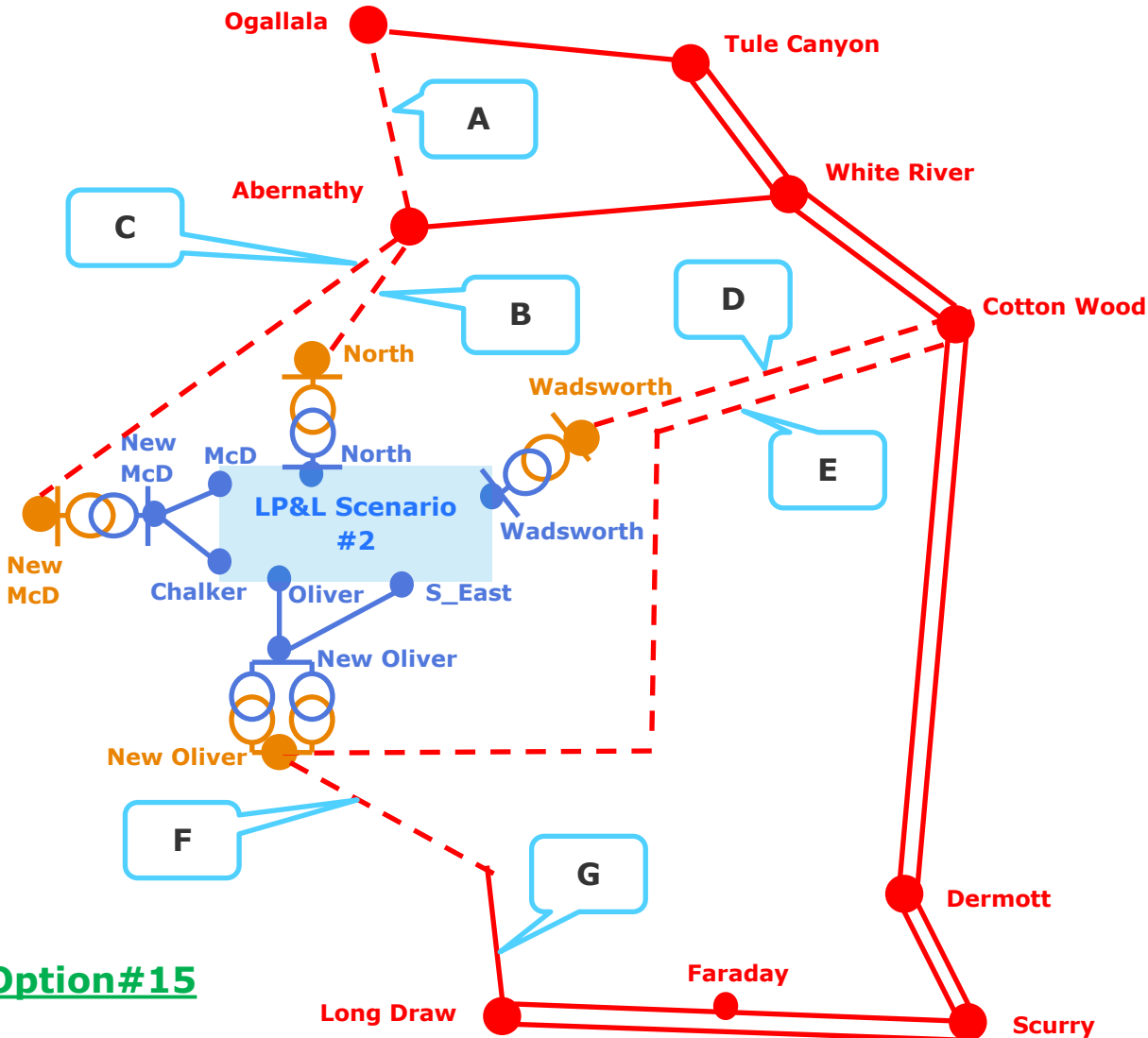
# Four (4) Sources to LP&L



- **Option#14:**
- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North
- **C** = 345kV line from Abernathy to New Mc Donald
- **D** = 345kV line from Cotton Wood to LP&L Wadsworth
- **E** = 345kV line from Cotton Wood to New Oliver
- **Lines D and E share same tower up to Wadsworth**
- **F** = Extend 345kV Grassland extension to New Oliver
- **G** = Existing 345kV line
- One 345/115kV Transformer at each LP&L POI
- Two 115kV lines from New Oliver to Oliver and S\_East
- Two 115kV lines from New McD to LPL McD and Chalker

## Option#14

# Four (4) Sources to LP&L

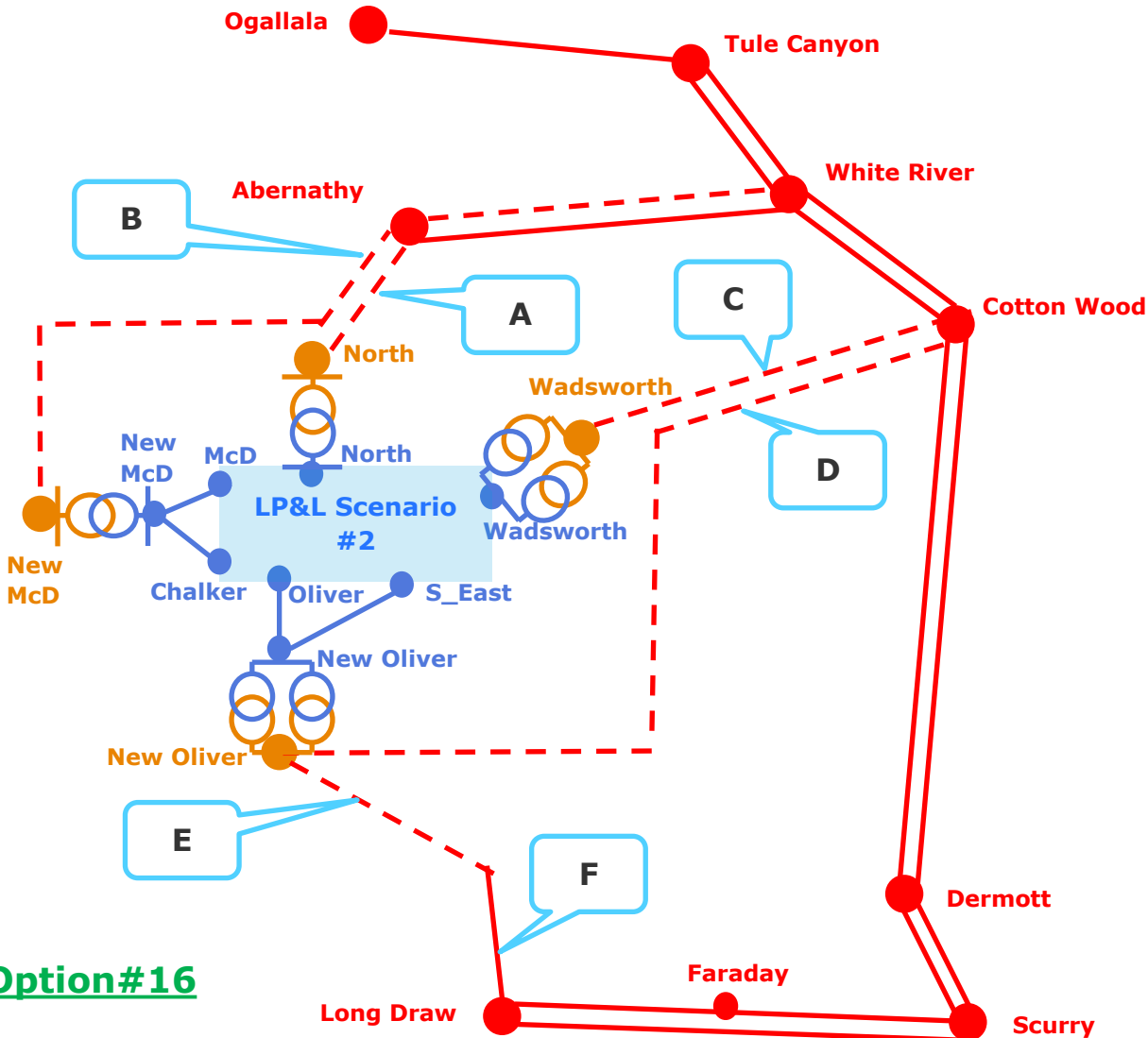


## Option#15:

- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North
- **C** = 345kV line from Abernathy to New McDonald
- **D** = 345kV line from Cotton Wood to LP&L Wadsworth
- **E** = 345kV line from Cotton Wood to New Oliver
- **Lines D and E share same tower up to Wadsworth**
- **F** = Extend 345kV Grassland extension to New Oliver
- **G** = Existing 345kV line
- Two 345/115kV Transformers at New Oliver
- Two 115kV lines from New Oliver to Oliver and S\_East
- Two 115kV lines from New McD to LPL McD and Chalker

## Option#15

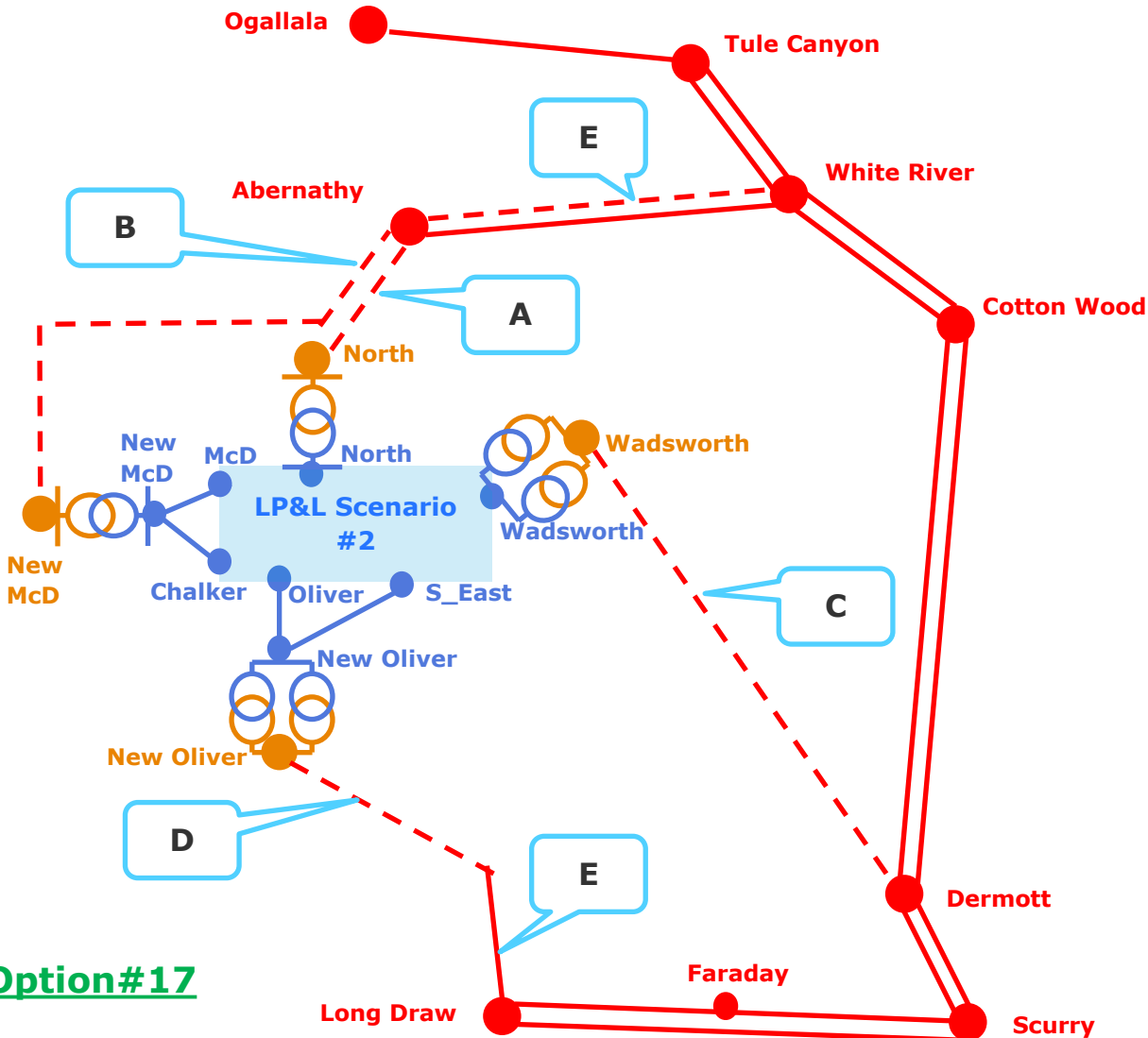
# Four (4) Sources to LP&L



- **Option#16:**
- **A** = 345kV line from Abernathy to LP&L North
- **B** = 345kV line from Abernathy to New McDonald
- **Lines A and B share same tower up to North**
- **C** = 345kV line from Cotton Wood to LP&L Wadsworth
- **D** = 345kV line from Cotton Wood to New Oliver
- **Lines C and D share same tower up to Wadsworth**
- **E** = Extend 345kV Grassland extension to New Oliver
- **F** = Existing 345kV line
- Add a 2<sup>nd</sup> circuit on existing White River to Abernathy
- Two 345/115kV Xfmrs at New Oliver and Wadsworth

**Option#16**

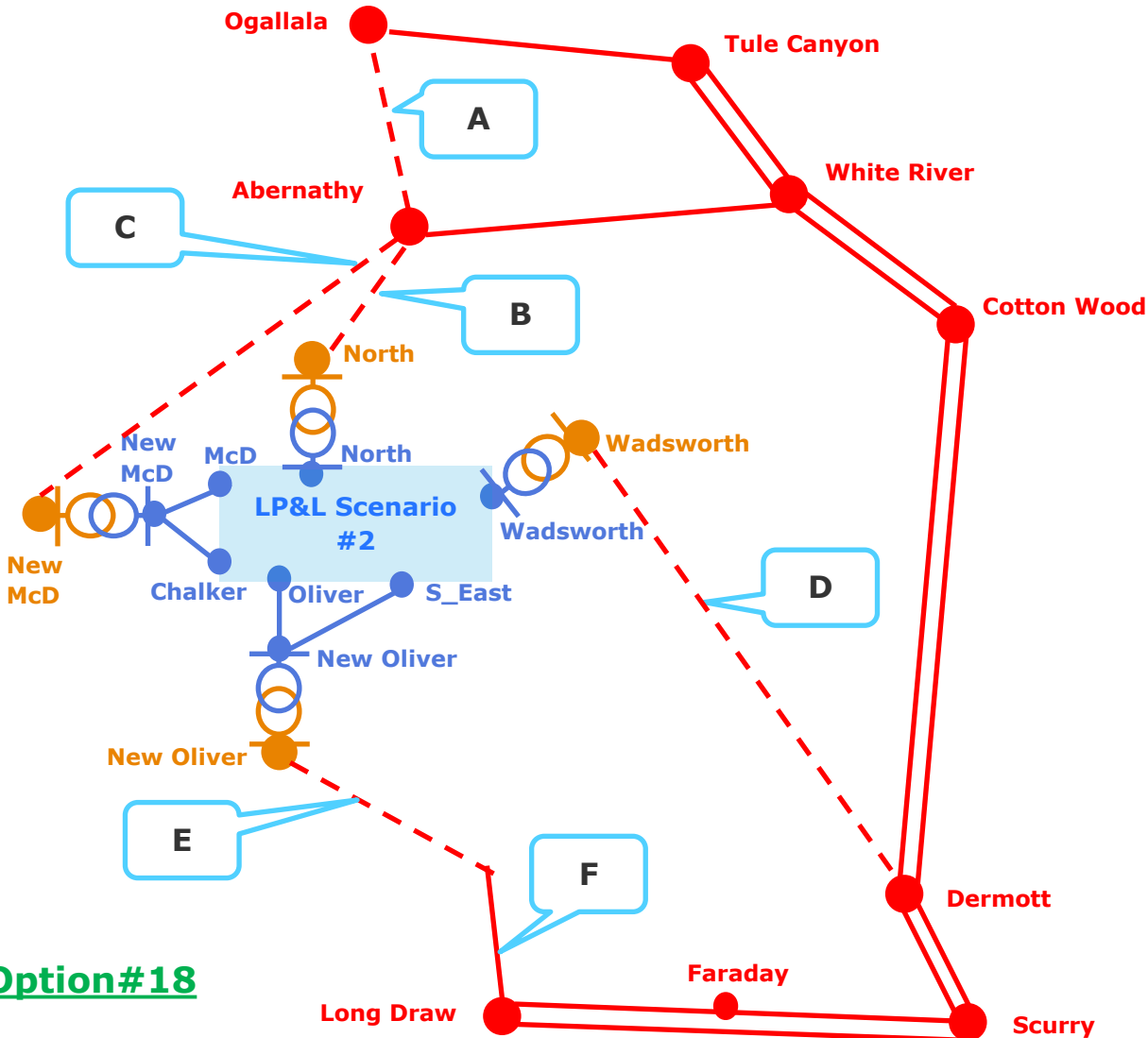
# Four (4) Sources to LP&L



- **Option#17:**
- **A** = 345kV line from Abernathy to LP&L North
- **B** = 345kV line from Abernathy to New McDonald
- **Lines A and B share same tower up to LP&L North**
- **C** = 345kV line from Dermott to LP&L Wadsworth
- **D** = Extend 345kV Grassland extension to New Oliver
- **E** = Existing 345kV line
- Add a 2<sup>nd</sup> circuit on existing White River - Abernathy
- Two 345/115kV Xfmrs at New Oliver and Wadsworth
- Two (2) 115kV lines from New Oliver to existing Oliver and South East
- Two (2) 115kV lines from New McDonald to existing McDonald and Chalker

## Option#17

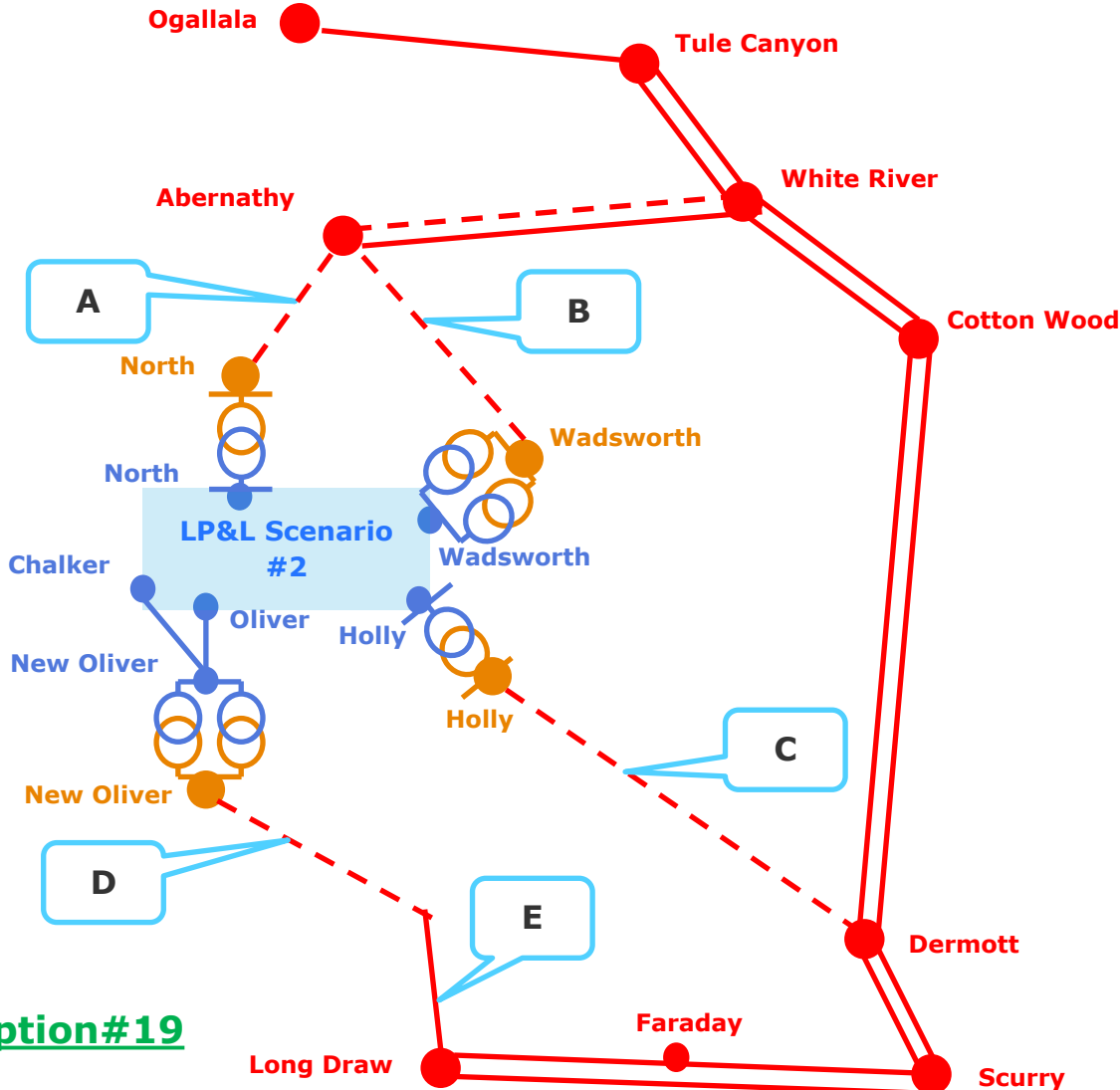
# Four (4) Sources to LP&L



- Option#18:**
- A** = 345kV line from Ogallala to Abernathy
  - B** = 345kV line from Abernathy to LP&L North
  - C** = 345kV line from Abernathy to New McDonald
  - D** = 345kV line from Dermott to LP&L Wadsworth
  - E** = Extend 345kV Grassland extension to New Oliver
  - F** = Existing 345kV line
  - One 345/115kV Transformer at each LP&L POI
  - Two (2) 115kV lines from New Oliver to existing Oliver and South East
  - Two (2) 115kV lines from New McDonald to existing McDonald and Chalker

## Option#18

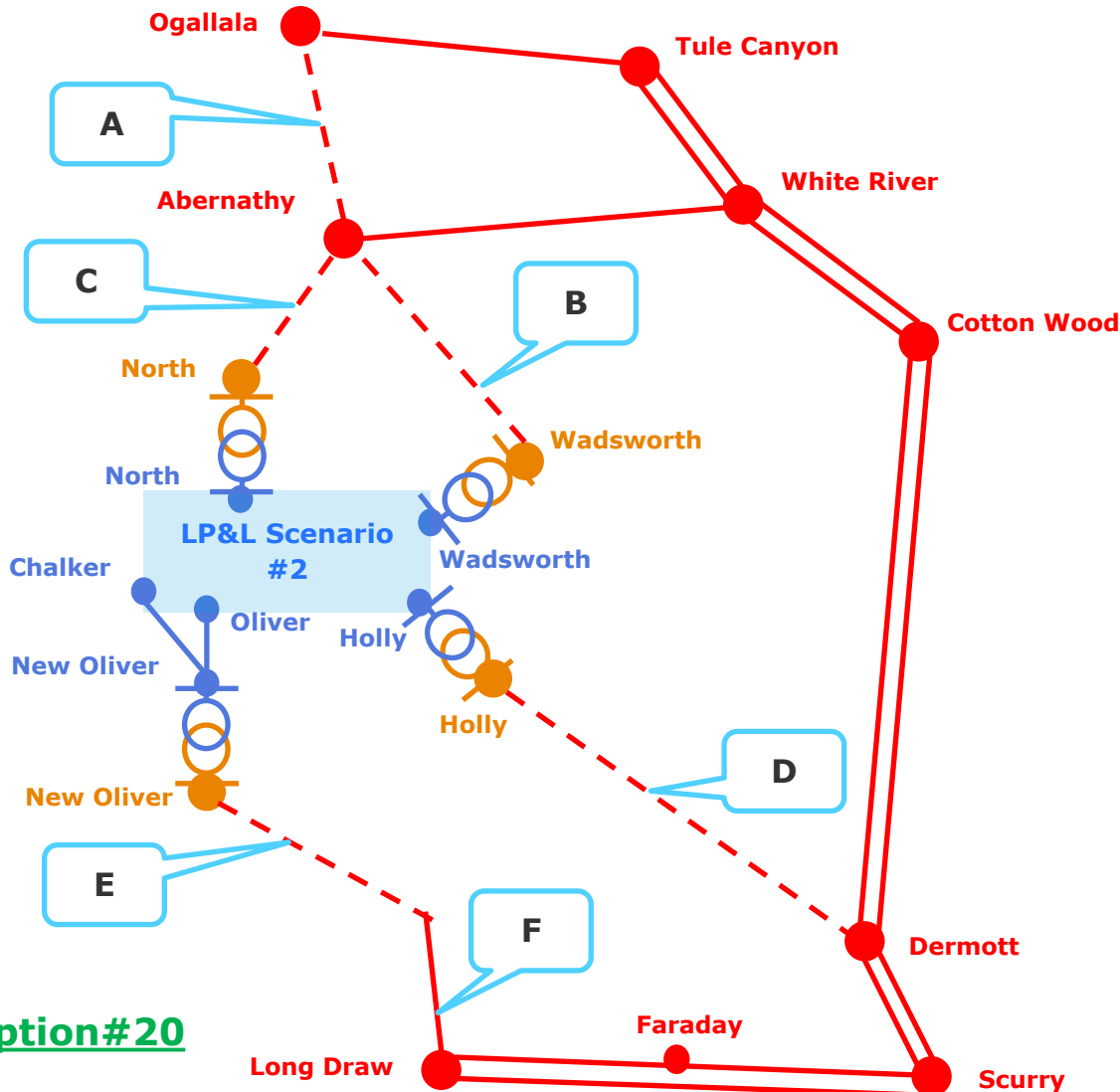
# Four (4) Sources to LP&L



- **Option#19:**
- **A** = 345kV line from Abernathy to LP&L North
- **B** = 345kV line from Abernathy to LP&L Wadsworth
- **C** = 345kV line from Dermott to LP&L Holly
- **D** = Extend 345kV Grassland extension to New Oliver
- **E** = Existing 345kV line
- Add a 2<sup>nd</sup> circuit on existing White River - Abernathy
- Two (2) 345/115kV Transformer at Wadsworth and New Oliver
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

## Option#19

# Four (4) Sources to LP&L



- **Option#20:**
- **A** = 345kV line from Ogallala to Abernathy
- **B** = 345kV line from Abernathy to LP&L North
- **C** = 345kV line from Abernathy to LP&L Wadsworth
- **D** = 345kV line from Dermott to LP&L Holly
- **E** = Extend 345kV Grassland extension to New Oliver
- **F** = Existing 345kV line
- One (1) 345/115kV at each LP&L POI
- Two (2) 115kV lines from New Oliver to existing Oliver and Chalker

**Option#20**