

Advancing Transmission Planning with Grid-Enhancing Technologies (GETs)

Practical Methodologies and Tools



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Session: *Planning and Operating Frameworks for GETs*

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Role of GETs & R&D / Needs Across the Value Chain



GETs bridge the gap between short-term and long-term transmission needs, to provide flexible, adaptable (least-regret) solutions, and optimize investment.



The Challenges

While some GETs have been available for many years, open questions remain as to how to characterize, plan, and operate these technologies to maximize their value.

R&D Needs Throughout the Value Chain

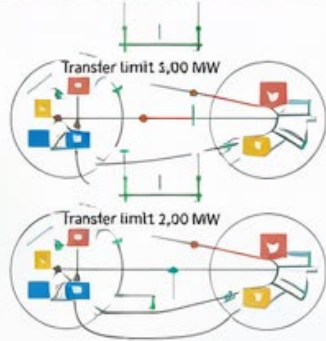
- Technology Evaluation
- **Integration in System Planning**
- Integration in System Operations.
- Technology Acquisition and Maintenance
- Incentive Design / Market Considerations

Outcome

- Embedding GETs into standard transmission planning through shared models, processes, and metrics
- **GETs treated as first-class options in every transmission plan — not pilot exceptions**

Grid-Enhancing Technologies

Advanced Power Flow Controllers



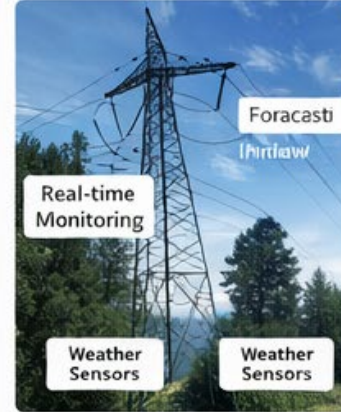
Reroutes power to lines with available capacity by adjusting impedance on lines

Advanced Conductors



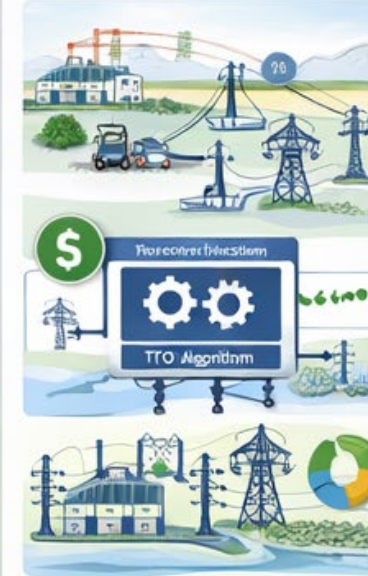
Operates at higher temperatures, allowing more power to flow

Dynamic Line Ratings



Updates thermal ratings of lines proactively through forecasting and in real time

Transmission Topology Optimization



Reconfigures network to efficiently manage congestion

GETs Planning Framework — At a Glance

✓ What the framework IS

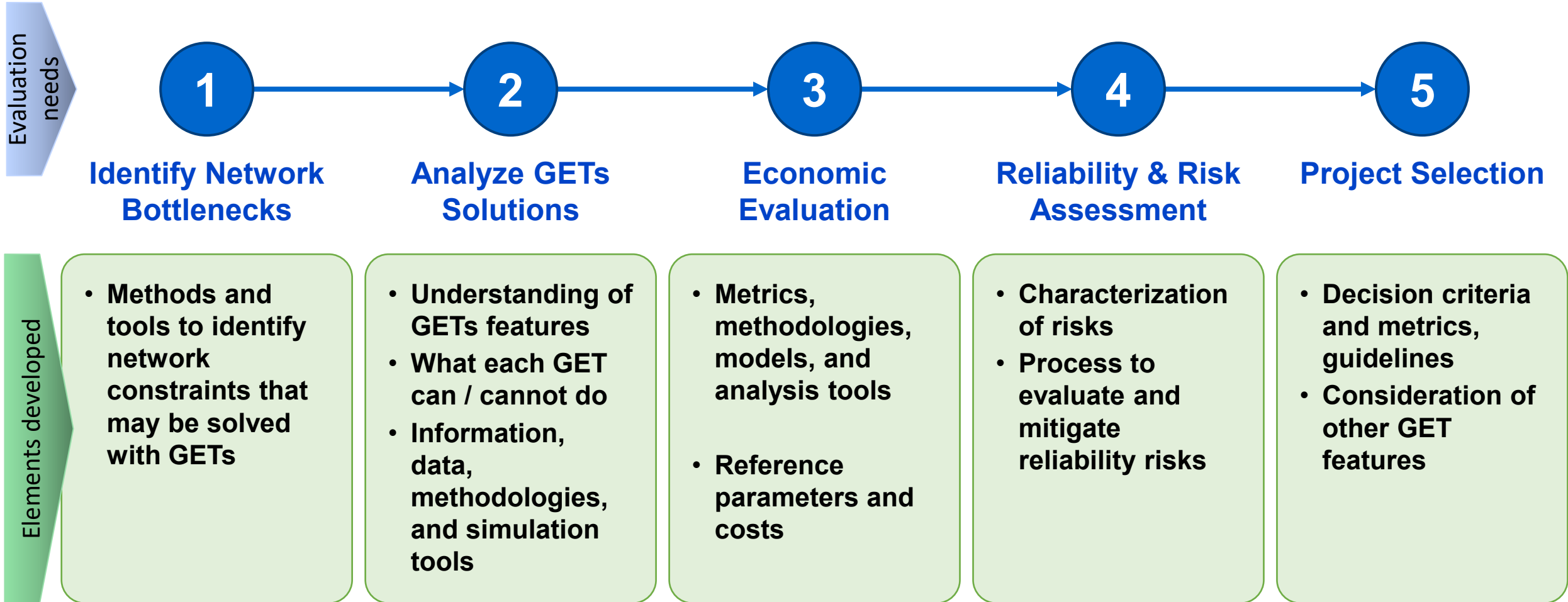
- ▶ **Methodologies, data, and tools** to design GET-based solutions and inform compliance with FERC O1920 and O2023, and other regulations
- ▶ **Guidelines** for performing studies
- ▶ **Leverages** existing processes, approaches, and tools
- ▶ **Adapts** to different transmission planning objectives:
 - Long-term regional / inter-regional
 - Market efficiency / economic projects
 - Reliability planning
 - Interconnection planning

✗ What it is NOT





























- ✗ Not a **strict, linear sequential process**
- ✗ Not intended to **replace existing planning processes** or methodologies — it complements them
- ✗ Not intended to **impose planning guiding principles or standards**

Helps with HOW to do the studies — not to prescribe WHAT or WHY to study

GET SET Planning Framework



GETs Salient Characteristics — At a Glance

Characteristic	Advanced Conductors	DLR	APFC	TTO
Capital Cost <i>Lower than expansion = favorable</i>	 Medium-high	 Low (sensors + software)	 Medium-high	
Lead Time <i>Shorter = favorable</i>	 Medium	 Months to 1 year	 1–2 years	
Outage Required <i>None = favorable</i>	 Unfavorable	 Yes, for sensor-based	 Limited	
Portability / Reversibility <i>Re-deployable = favorable</i>	 Unfavorable	 Yes	 High; voltage-agnostic	 N/A (software)
Modularity / Scalability <i>Incremental expansion</i>	 Unfavorable	 High — add sensors	 High — modular units	 High — scales with compute
Firm Transmission Capacity <i>Guaranteed capacity = favorable</i>	 Favorable	 Unfavorable	 Favorable	 Case-dependent
Operational Impact <i>Active control = favorable</i>	 Moderate / context-dependent	 Moderate / context-dependent	 Favorable	 Moderate / context-dependent

 Favorable

 Moderate / context-dependent

 Unfavorable

Screening Assessment — GET Suitability Matrix

Transmission Need	Advanced Conductors	APFC	DLR	Topology Optimization
Reliability-driven <i>Criteria violations needing solutions</i>	WELL-SUITED Permanent capacity; costly on long lines	WELL-SUITED Thermal overloads with alternate paths	CONDITIONAL Statistical capacity only	CONDITIONAL Meshed networks; no safety margin
Congestion / Market Inefficiencies <i>Economic-benefit driven</i>	WELL-SUITED Best on short lines; high cost	WELL-SUITED Responsive to economic signals	CONDITIONAL Boost during favorable conditions	WELL-SUITED Low cost if alternate paths exist
Loop Flows & Contract Path <i>Unscheduled flows; inequitable cost</i>	NOT SUITED No direct flow control	WELL-SUITED Manages loops; enforces contract paths	NOT SUITED No direct flow control	CONDITIONAL Depends on topology & operations
Short-Term Operations <i>Fast, low-cost, flexible</i>	NOT SUITED Not for interim solutions	CONDITIONAL Mobile units redirect flows quickly if capacity is available	WELL-SUITED Leverages wind/cooling conditions	CONDITIONAL Easy, fast; depends on topology
Adaptive / Uncertain Future <i>Least-regret, redeployable</i>	NOT SUITED Permanent; hard to redeploy	WELL-SUITED Flexible; repurposed as needs shift	CONDITIONAL Moderately flexible; low cost	WELL-SUITED Software-based; highly flexible
Aging Infrastructure <i>Replacement / capacity upgrade</i>	WELL-SUITED Extends asset life; no new corridors	CONDITIONAL Bridge solution; defers full rebuild	NOT SUITED Not a long-term strategy	CONDITIONAL Bridge; defers full rebuild



Well-suited



Conditional / context-dependent



Not well-suited

Analyze GETs Solutions

Advanced Conductors



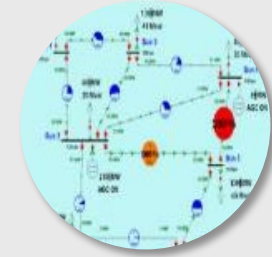
Advanced Power Flow Controllers



Dynamic Line Ratings



Topology Optimization



Advanced Conductors:

- An approach to analyzing the feasibility of reconducting a line with AC with minimal structure changes
- Outcome: conductor selection, parameter, cost

APFC:

- Methodology and tools to identify the optimal location, size, and control parameters
- Optimization tools
- Investment and O&M cost reference

DLR:

- Statistical characterization of rating over a significant period of time.
- Capital investment reduction
- Risk assessment
- Investment and O&M cost reference

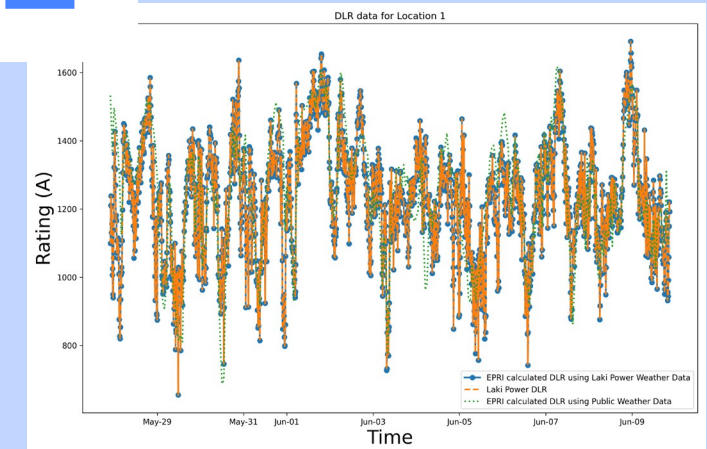
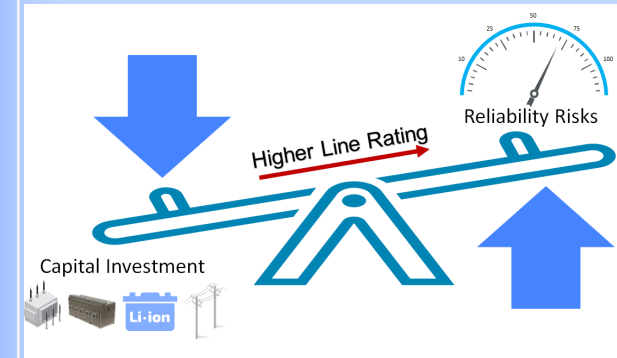
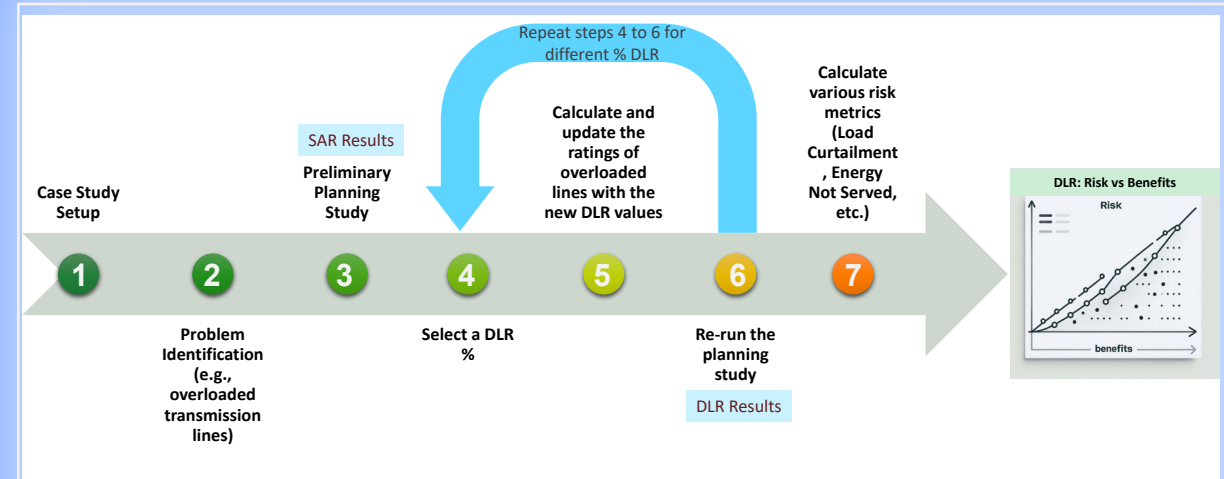
TTO:

- Analysis of TTO in long-term planning.
- Complement long-term solutions
- Risk assessment
- Compliance with regulation (FERC 1920)
- Use of existing software.
- Build upon case studies

Methodologies and handy tools and information is being developed for each technology

DLR Solution Analysis and Design

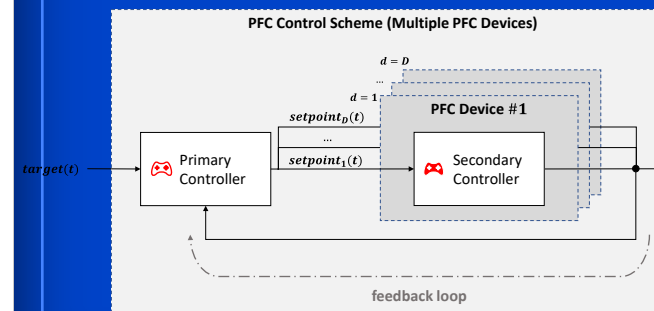
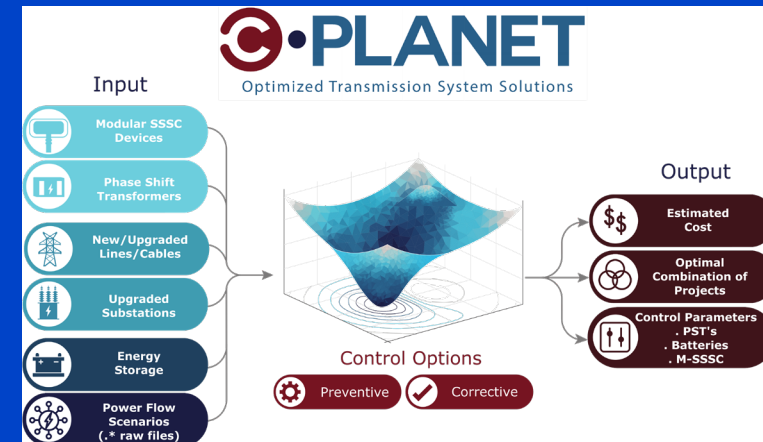
- Statistical characterization of ratings over a significant period of time
- Capital investment reduction (Benefit)
- Benefits vs. risk assessment
- Investment and O&M cost reference
- **A handy tool to create synthetic DLR data for planning studies:**
 - Use available weather information (NOAA, ERAS)
 - GIS coordinates
 - Conductor parameters
- DLR Reference Cost
 - *Utility Cost Considerations in the Implementation of Dynamic Line Rating (DLR) Systems.* EPRI, Palo Alto, CA: 2026. 3002034763



APFC Solution Analysis and Design

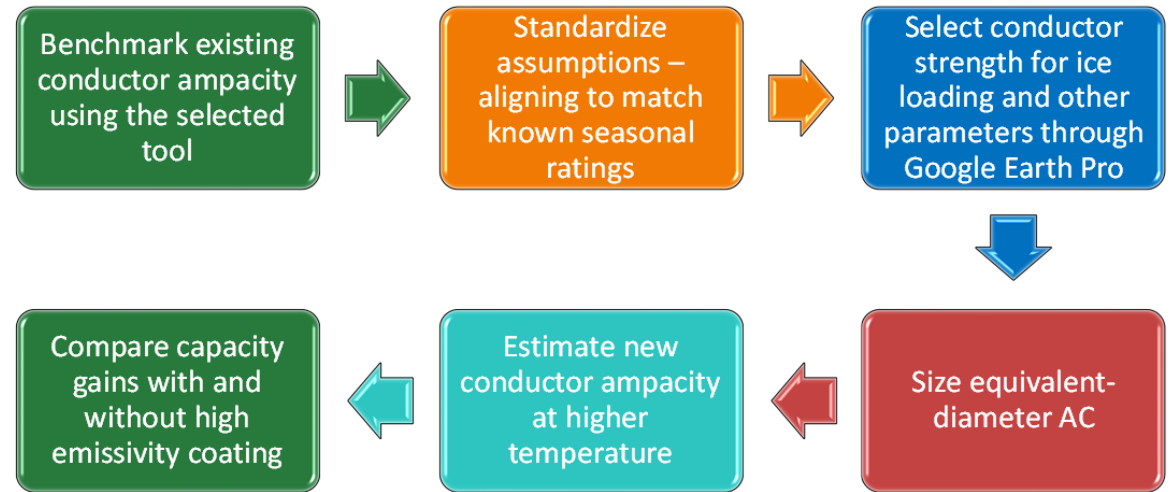
- Methodology and tools to identify the optimal location, size, and control parameters
- Optimization tools (e.g., CPLANET software)
- Alternative/ complementary methods
- Investment and O&M cost reference:
 - Reference cost provided by Smart Wires Inc.
 - Control and implementation consideration
- Multiple case studies

Approach	Description	Key Advantages	Limitations
Brute Force	Evaluates every possible location and combination.	Conceptually simple and exhaustive.	Very time consuming and does not guarantee an optimal solution.
Sensitivity Based	Examines how power flows respond to SSSC injections.	Fast and scalable for large grids.	Impact is local and provides initial guidance but not an optimal solution.
Optimization Based	Uses optimization techniques to determine device placement. Software tools like CPLANET can be used.	Produces an optimal solution and is efficient.	Slower compared to sensitivity based approaches.



Reconductoring with AC Solution Analysis and Design

- A practical methodology to analyze the feasibility of reconductoring with AC and estimate cost, parameters and performance
- Assumption is to replace with similar conductor diameter
- Simplified, benchmark-based costs for screening
- Validate with detailed, location-specific estimates before decisions
- Available vendor tools can be used with specific data or assumed data to calculate the potential new ratings for AC considerations: Example Tool: [EPRI High Temperature Conductor Matrix tool](#)

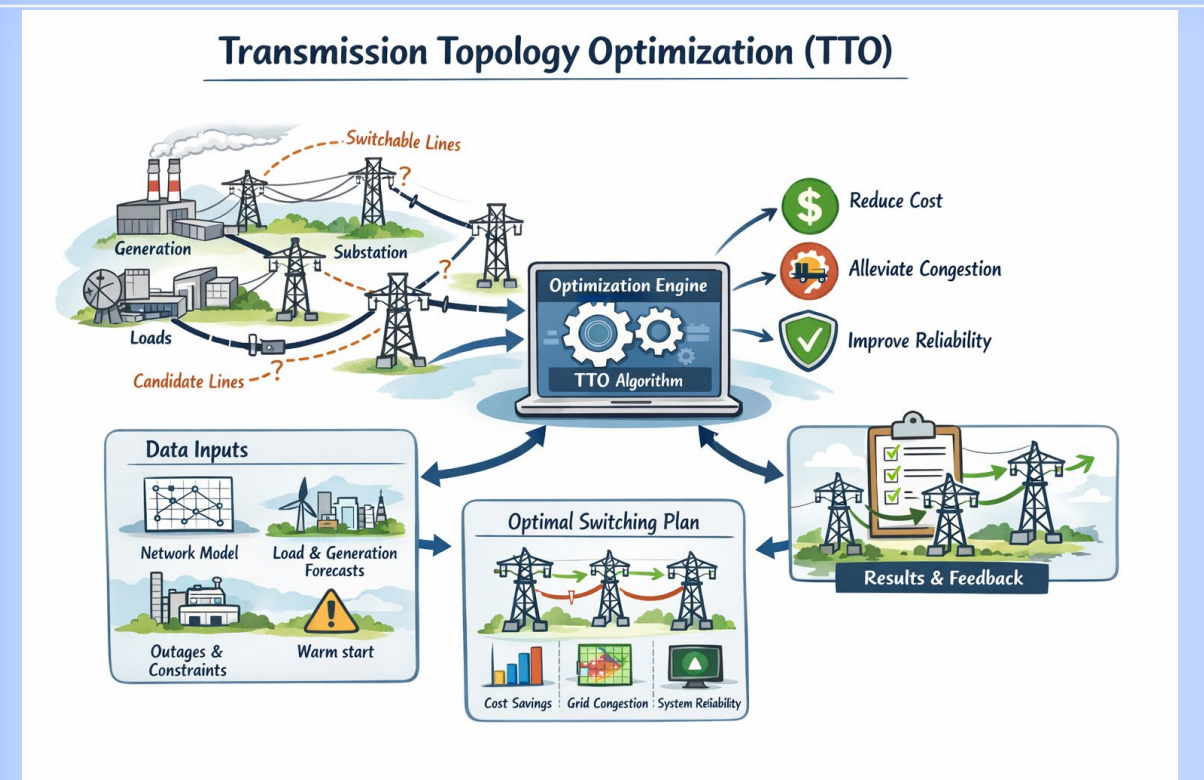


	Ideal/utility Source	Generic/public Source
Conductor temperature, characteristics	Transmission Owner or AC Manufacturer or AC vendor	Online or generic available information
Location Information		Google Earth Pro tool
General Parameters		Adjusted to align with known seasonal static line ratings

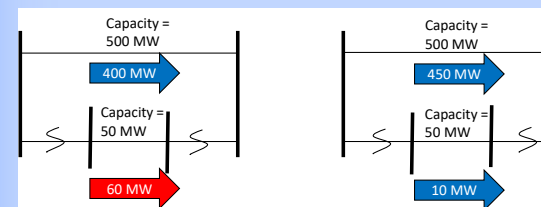


TTO Solution Analysis and Design

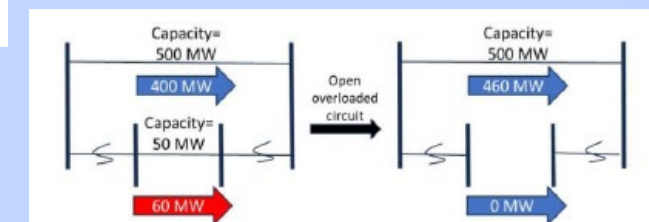
- Evaluation of transmission switching as a transmission alternative to traditional network upgrades
- Can TTO software be used as planning solution?
 - Process and tools needed
 - Candidates for permanent configuration changes in the long-term design.
 - Any specific scenario characteristics
- Benefits and risks, comparison with traditional alternatives
- Case studies with GET SET utility members



TTO option A: Split the bus



TTO option B: Open the overloaded circuit

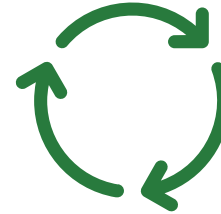


Reliability Assessment



Conventional reliability metrics that apply to any transmission solution:

- Contingency analysis (TPL)
- Transient stability following disturbances
- Voltage stability margins
- Various system conditions



Technology-specific considerations unique to particular GETs:

APFC: control modes and operation under different conditions, control scheme robustness and selectivity.

DLR: statistical assessment of line capacity, uncertainty in weather forecasting

TTO: scenarios to analyze (typical scenarios may not be sufficient), redefinition of contingencies

Reliability and risk assessment ensures that proposed GETs solutions maintain or enhance system reliability while managing implementation and operational risks to acceptable levels

Risk Assessment

- Operational risks encompass potential issues that might arise during the ongoing operation of the deployed technology:
 - Technology performance and failure risk
 - Integration and complexity risks

Advanced Conductors:

- Installation quality issues
- Long-term material performance uncertainty
- Compatibility with existing structures

APFC:

- Equipment failure or malfunction
- Adverse interactions with system protection
- Cybersecurity vulnerabilities
- Control scheme dependability and security

DLR:

- Sensor failure or measurement errors
- Communication system failures

TTO:

- Unintended consequences of switching actions
- Operator error in complex networks
- Software bugs or calculation errors
- Inadequate study of all network configurations

Systematically identifies, evaluates, and develops mitigation strategies for risks associated with the GETs solution

Project Selection - Selection Criteria

Economic metrics:

- Benefit-Cost Ratio
- Net Present Value
- Payback Period
- Risk-Adjusted Returns: Economic value accounting for uncertainties

Technical Performance :

- Effectiveness: Degree to which the solution addresses identified need
- Reliability: NERC compliance and system security
- Robustness: Performance across a range of conditions
- Compatibility: Integration with existing systems

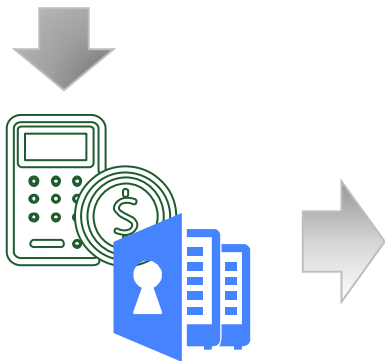
Implementation :

- Deployment Timeline
- Permitting and Siting: Complexity of regulatory approvals
- Construction Risk
- Environmental Impact
- Outage needed
- Technology familiarity
- Vendor viability

Strategic value:

- Flexibility and Adaptability: Ability to respond to changing conditions
- Modularity: Incremental expansion capability
- Reversibility: Ability to relocate or remove if conditions change
- Environmental or community impact

Quantitative & Qualitative Assessment



Alternatives	Economic		Implementation		Strategic Value	
	✓	○	✓	○	✓	○
Alternative 1	○	○	○	○	○	○
Alternative 2	○	○	○	○	○	○
Alternative 3	○	○	○	○	○	○
Alternative 4	○	○	○	○	○	○

Summary

✓ Framework Highlights

- Provide concrete methods for GETs solution selection
- Technology use case matrix with real-world results
- Screening tools with upgrade cost estimates
- Integrate operator feedback and lessons learned loops
- Comprehensive risk assessment and multidimensional comparison and selection criteria

🕒 Remaining Objectives/ Challenges

- Address regional impacts beyond utility-level analysis
- Include resilience metrics and multi-dimensional comparisons
- Capital expenditure frameworks for GETs investments still evolving
- Capitalizing GETs in rate base considering multiple benefits

Optimal Solutions using GETs: Move GETs from "special studies" to standard processes and evaluation criteria



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