Bringing the Grid to Life:

White Paper on the Benefits to Customers of Transmission Management Technologies

Working for Advanced Transmission Technologies (WATT) Coalition

www.watt-transmission.org

White Paper

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Executive Summary

Most forms of infrastructure are being transformed with modern monitoring, data communication, data analysis, and remote control systems. The electric transmission system is poised to be the next sector. A number of proven, advanced technologies exist which can help optimize the existing transmission grid. These technologies can variously allow hidden transmission capacity to be identified and utilized, reduce power flow on overburdened lines, and/or reconfigure existing grid elements to optimize various operational scenarios. These advanced technologies can be applied singly or in combination.

Widespread deployment of these technologies could reduce the cost of electricity to consumers by as much as $2 billion per year while improving reliability and resilience.

FERC policy since the Energy Policy Act of 2005 has resulted in regulations which offer incentives for advanced technology only if it is; a) part of a grid expansion proposal, and, b) demonstrated there is some risk to its deployment. This structure does not encourage the deployment of newer but proven technologies which can improve grid operations and reduce operational costs.

Many existing regulatory structures are designed to directly or indirectly incentivize large capital investments. This also serves to dis-incent investment in relatively low-cost technologies that may offer significant operational benefits.

Different options are available to FERC to more broadly encourage the consideration of these technologies. These include:

1. Invite tariff filings to improve the incentives for transmission owners;
2. Provide guidance and direct RTO/ISO transmission planners to incorporate consideration of advanced technologies in both operations and planning;
3. Develop and allow for the use of performance metrics (e.g., congestion cost reduction) which could be factored into revenue requirements;
4. Hold a technical conference and staff inquiry to produce and share information about the technologies and encourage rigorous discussion regarding their deployment.

I. Introduction

Across the country $6 billion worth of extra costs are paid annually by customers due to transmission congestion.[1] New and expanded transmission facilities will help but will take time and face cost allocation and permitting difficulties. Thus, optimizing delivery over the existing network may be the only way to reduce congestion in many instances and may complement grid expansion in others. Collectively, network optimization technologies could save $2 billion per year or $20 billion over ten years.[2] Reliability and resilience can also be improved significantly with the improved system condition monitoring that these technologies provide. The Working for Advanced Transmission Technologies (WATT) Coalition is pleased to offer these suggestions to help the Commission ensure customers benefit from reliable service at just and reasonable rates by removing barriers to advanced transmission technology deployment.

II. All Infrastructure Is Becoming Smart

Telecommunications, water, sewage, transportation and other infrastructure networks are being transformed by a rapidly advancing and common suite of technologies: remote monitoring, control algorithms, data communications, and computing power. Often called "smart" systems and utilizing the Internet of Things (IoT), these networks are taking advantage of the improved technology, lower cost, and synergy that is taking place in these four areas. Sensor costs have fallen due to mass production in smart phones. Computing power continues to follow Moore's law of steady improvement. Communications network capacities increase every year. Algorithms are becoming ever more sophisticated. These four areas work together to produce productivity and performance opportunities in many sectors.

In transportation, "Remote Condition Monitoring" is being used to monitor the integrity of railways, bridges, and highways. Rail systems are moving towards a "predict and prevent" approach using remote monitoring and analysis.[3] Road system monitoring is replacing manual condition monitoring using 3-D sensors.[4] Most drivers are now utilizing GPS apps such as Google Maps or WAZE to optimize their navigation based on dispersed monitoring of traffic conditions, data communication, and optimization algorithms.

Water and wastewater systems are benefitting from IoT as well. Water leakage can be detected and prevented with new low-cost sensing and communications. Wastewater systems can remotely monitor and quickly respond to chemicals identified in their systems.[5]

Energy applications abound. From oil wells to coal plants to wind turbines, downtime is being reduced via remote monitoring and predictive maintenance.[6]

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[1] See Appendix A.
[2] See Appendix A.
[3] https://www.arcweb.com/blog/remote-condition-monitoring-boost-rail-asset-management
[4] http://www.sciencedirect.com/science/article/pii/S2352146516304434
[5] https://www.wwdmag.com/meters/how-optimize-infrastructure-remote-monitoring

The transmission sector is ripe for improvement with this suite of technologies. A McKinsey consulting report stated: "T&D companies can manage assets more efficiently thanks to improvements in technology. Sensors, communications devices, and other hardware that allow objects to be tracked and controlled remotely have become increasingly affordable and reliable. So have the analytical tools for processing, interpreting, and responding to data from equipment."[7] The term "smart grid" tends to apply to retail metering and systems at the end of the grid; the technologies described here affect the heart of the bulk power network.

III. New Technologies Can Optimize the Transmission Bulk Power Network

The transmission grid is typically operated in a static and passive way. Transmission operators traditionally use fixed ratings, based on planning calculations; fixed settings, without power flow controls; and fixed topology/configuration, using normal (planning) open/close breaker status. This fixed grid topology was appropriate to deliver power from large central power plants to load, but greater grid flexibility is required as the generation mix shifts to variable and renewable sources.

There are a set of cost-effective technologies that can increase the flexibility, reliability and utilization of the transmission grid. These technologies have improved significantly in recent years, benefitting from the extraordinary increase in computing power and data collection and management systems that are transforming most other sectors of the economy. R&D efforts including DOE's ARPA-E and other program offices have helped them along. They have also all benefitted from pilot projects and learning-by-doing on some systems in the US and abroad. When Congress passed the Energy Policy Act of 2005 encouraging FERC to deploy advanced technologies, these network optimization options were not sufficiently developed for wide commercialization. They are now. While the costs vary by technology and application, one can think of their costs in the range of 1 percent of the cost of new conductors. Leading technology options include:

Dynamic Line Ratings

Dynamic Line Ratings (DLR) increase capacity on existing transmission lines by calculating ratings based on actual monitored conditions rather than fixed worst-case assumptions. With DLR, even a relatively low amount of wind can significantly increase the rating of a line and reduce the impact of curtailments and congestion on customers and producers of wind energy. DLR systems also provide forecasted ratings up to 48 hours ahead, and improve reliability by alerting operators to conditions such as clearance violations.

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[6] http://www.oilgasmonitor.com/take-control-condition-monitoring/, https://www.automation.com/library/articles-white-papers/condition-monitoring/improving-plant-production-with-wireless-condition-monitoring

[7] https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/how-analytics-can-improve-asset-management-in-electric-power-networks

Estimates of increased capacity have been 40 percent[8], 30 to 70 percent, and 30 to 44 percent on three different tests.[9] Notably, the same change in wind speed that can increase a line's capacity is often the cause of increased demand for that capacity from customers or producers of wind energy.[10] DLR generally allows more flow over the course of a year than would otherwise be allowed, but also detects situations when flows should be reduced to maintain safe and reliable operation.

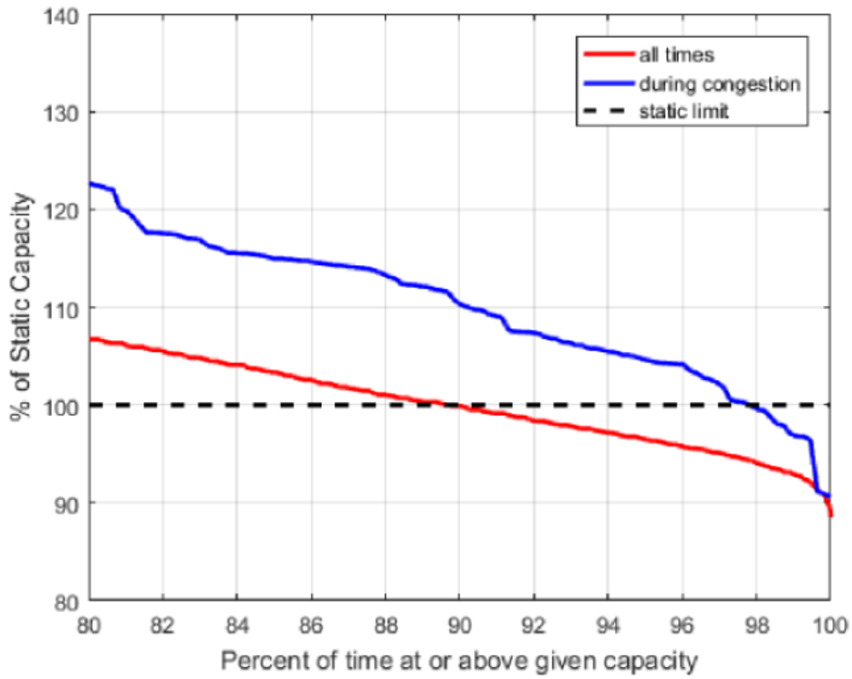

Figure 1: Modeled Capacity on Kansas Transmission Line[11]

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[8]Jake Gentle, Warren Parsons, Michael West, Catherine Meibner, Philip Anderson, "Increasing Transmission Capacities By Dynamic Line Rating Based on CFD."
https://watttransmission.files.wordpress.com/2017/11/2015_awea_dlr_validation_final.pdf

[9] US Department of Energy, Dynamic Line Rating Systems for Transmission Lines, https://www.smartgrid.gov/files/SGDP_Transmission_DLR_Topical_Report_04-25-14_FINAL.pdf, April 2014, https://www.smartgrid.gov/files/SGDP_Transmission_DLR_Topical_Report_04-25-14_FINAL.pdf

[10] Doug Bowman and Jack McCall, "Reducing Contingency-based Windfarm Curtailments through use of Transmission Capacity Forecasting," CIGRE US National Committee 2017 Grid of the Future Symposium. https://watttransmission.files.wordpress.com/2017/11/reducing-curtailment-through-tcf-cigre2017-bowman-mccall.pdf

[11] Verga, N. Pinney, and J. Marmillo, "Incorporating Dynamic Line Ratings to Alleviate Transmission Congestion, Increase Wind Resource Utilization, and Improve Power Market Efficiency," CIGRE US National Committee 2016

DLR supports grid resilience by offering condition-based line capabilities when contingencies occur. For example, when a line trips, the increased flow on other lines may be tolerable based on actual conditions even if the static setting would lead to a protective action to trip the line. Relays could be programmed to take actual conditions into account.[12]

DLR technology can be rapidly deployed as it is minimally invasive and usually does not require de-energization of transmission lines and the resulting complex outage coordination required. A variety of systems have been demonstrated, both on lines, directly measuring temperature and other properties, and in a non-contact form, measuring Electromagnetic Fields (EMF).[13]

DLR has been deployed on a large scale in Europe. Belgium's Transmission System Operator Elia deployed systems on all of its critical overhead lines to France and the Netherlands, helping it maximize import capability after the retirement of three large power stations.[14]

Advanced Power Flow Control

Power Flow Control is a set of technologies that effectively push or pull power away from overloaded lines and onto underutilized corridors within the existing transmission network. Advanced power flow control provides this same function with advanced features such as the ability to be quickly deployed, easily scaled to meet the size of the need, or redeployed to new parts of the grid when no longer needed in the current location.

Topology Optimization

Transmission topology optimization is a software technology that automatically identifies reconfigurations of the grid to route power flow around congested or overloaded transmission elements, taking advantage of the meshed nature of the power grid. The reconfigurations are implemented through switching on/off existing high voltage circuit breakers. By more evenly distributing flow over the network, topology optimization increases the transfer capacity of the grid. Acting as a grid configuration "search engine," topology optimization can reduce congestion by up to 50 percent and

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Grid of the Future Symposium. https://watttransmission.files.wordpress.com/2017/11/cigre-gotf-2016-genscape-finalsubmission1.pdf

[12] J.C. McCall, T. Goodwin, "Dynamic Line Rating as a Means to Enhance Transmission Grid Resilience," CIGRE US National Committee 2015 Grid of the Future Symposium.

[13] Marmillo, N. Pinney, B. Mehraban, S. Murphy, "A Non-Contact Sensing Approach for the Measurement of Overhead Conductor Parameters and Dynamic Line Ratings," CIGRE US National Committee 2017 Grid of the Future Symposium, https://watttransmission.files.wordpress.com/2017/11/genscape-cigre-gotf-whitepaper-2017.pdf

[14] Bourgeois, Raphael and Lambin, Jean-Jacques, "Dynamic Ratings Increase Efficiency," T&D World, 4/4/2017. http://www.tdworld.com/print/32183

improve response to contingencies, supporting reliability and resilience.[15] It can reduce renewable energy curtailment by up to 40 percent.[16] Optimization methods are much cheaper than hardware options such as phase angle regulators (PARs).[17]

Technology Synergies

Any of these technologies can be used in isolation or in combination with each other to achieve additional benefits and flexibility in operation of the grid.

IV. The Incentive Problem

The famous regulatory economist Alfred Kahn was fond of reminding policy makers that "all regulation is incentive regulation." In other words, whatever compensation mechanism regulators put in place will influence how the regulated entities act. There are no regulatory approaches that are fully aligned with efficient behavior including efficient innovation; each has pros and cons, including the regulations currently in place for the US transmission sector.

The US transmission sector is regulated by FERC using a form of cost-of-service regulation. Common FERC practice is for utilities to place investments into their transmission rate base which is recovered through RTO tariffs. Investments are generally deemed to be those necessary to meet reliability criteria or RTO planning requirements. Each transmission owner submits its revenue requirement in order to recover those costs. They are "formula rates," meaning they operate automatically, with expenditures reported to FERC in informational filings for regulatory review and audit, but not as regular rate cases as is more typical for regulated industries. Return on Equity in transmission investments is often around 11 percent.

Under this regulatory regime, utilities profit more on large capital investments than on smaller ones that may achieve the same purpose. This dynamic has been well established in the economics literature

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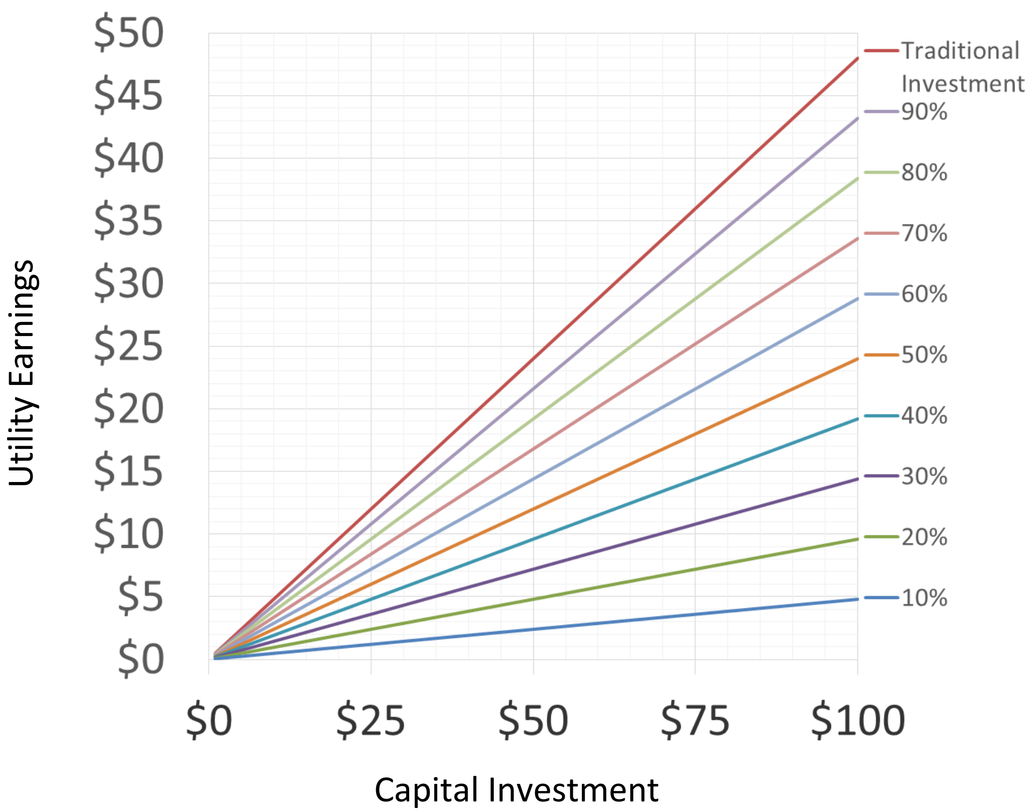
[15] Pablo A. Ruiz, "Transmission Topology Optimization Software – Operations and Market Applications and Case Studies," ERCOT Emerging Technologies Working Group Meeting, Austin, TX, December 2016, http://www.ercot.com/content/wcm/key_documents_lists/85542/05._Transmission_topology_control_--_ERCOT_ETWG_12616.pdf

[16] Pablo A. Ruiz, Michael Caramanis, Evgeniy Goldis, Xiaoguang Li, Keyurbhai Patel, Russ Philbrick, Alex Rudkevich, Richard Tabors, Bruce Tsuchida, "Transmission Topology Optimization – Simulation of Impacts in PJM Day-Ahead Markets," FERC Technical Conference on Increasing Market Efficiency through Improved software, Docket AD10-12-007, Washington, DC, June 2016, http://newgridinc.com/wp-content/uploads/2016/06/PRuiz-FERCTechConf-28Jun2016.pdf, slide 11.

[17] T. Bruce Tsuchida, Xiaoguang Li, Pablo A. Ruiz, "Reducing Renewable Curtailments Through Flexible Operation," North American Wind Power, Feb 2014, pp. 10-12. https://nawindpower.com/online/issues/NAW1402/FEAT_03_Reducing-Renewable-Curtailments-Through-Flexible-Operation.html

for decades and applies across many sectors including water systems, telecom, and electricity.[18] The graphic below shows how a reduction in capital costs results in a penalty to the utility through decreased revenue. The vertical axis is a measure of how much revenue a utility earns on a project. The horizontal axis represents the cost of traditional transmission investment cost. For example, for a $50M traditional investment, a utility earns just under $25M in present value post-tax earnings. For an advanced transmission solution that is 50% of the capital cost of the tradition solution ($25M), the utility earns just under $12M in post-tax earnings (present value). The utility loses ~$12M in earnings when they choose the advanced technology solution. This is no incentive for innovation; there is a penalty for saving consumer money.



Innovations would be affected by this capital bias because they are less capital intensive. Some innovation activities are based on operations rather than capital assets. Operating costs are only recovered dollar for dollar, passed through in rates whereas capital expenditures are rewarded with a return on the investment. In addition, utilities do not profit if they reduce operations expenditures. The activities may also be discouraged because they require more management oversight since they are operational, managed by human resources. The operations also sometimes require new functions and

[18] Averch, Harvey; Johnson, Leland L. (1962). "Behavior of the Firm Under Regulatory Constraint". *American Economic Review*. **52** (5): 1052–1069. JSTOR 1812181.

organizational capabilities that require management attention which is a valuable and limited resource. These factors result in a bias against activities that include more operational expense.

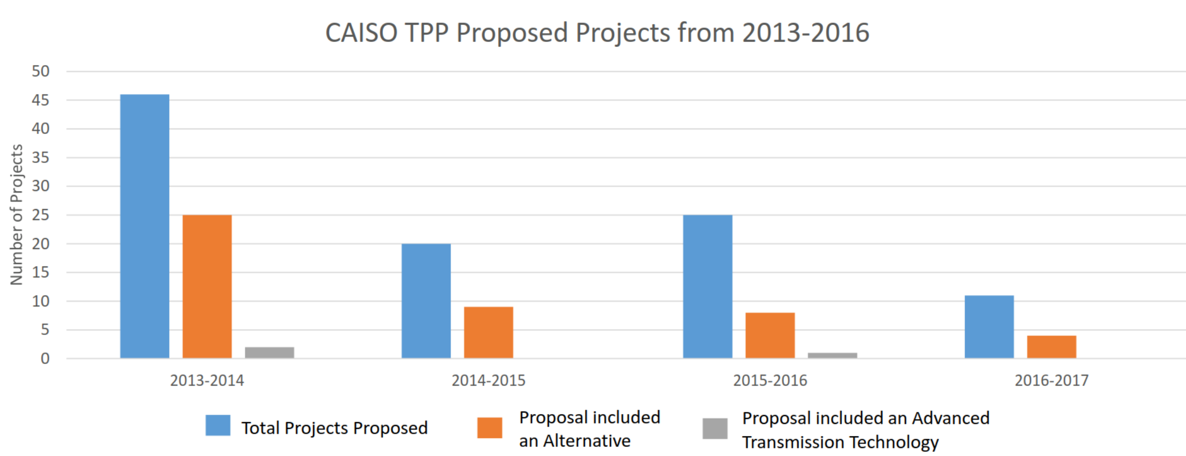
In this regulatory structure, there is little upside for innovation. An investment must be “used and useful” to qualify for cost recovery, so there is little tolerance for failure. The value of successful new approaches is not fully captured by the transmission owner, so earnings from those instances do not make up for the ventures that do not pan out. This is fairly common across regulated industries; it is hard to demonstrate in contested proceedings that consumers should be forced to pay for the innovations that do not succeed.

Risk aversion is prevalent in the transmission sector more than other regulated industries because of reliability risks. It is generally a good thing that systems operate with a safety margin and changes to the grid such as interconnections of new generators are carefully studied to ensure reliability is preserved. The tendency towards risk aversion will not and should not change, but it should be recognized as a factor in slowing down innovation.

Activities with broadly dispersed beneficiaries are not rewarded in this structure with transmission owners each covering small parts of the RTO footprint. Increases in delivery capacity and reliability cannot be precisely assigned to specific users on an integrated AC network. The grid is a public good, meaning the common benefits exceed the private benefits. Investments made by one entity benefit others more than itself, which makes it hard to justify the investment.

Innovations that improve reliability are often under-valued because reliability standards and expectations often take time to recognize the value of new methods. One clear example is that automobile safety improved once seatbelts were required on all automobiles. Similarly, grid reliability will improve as once advanced grid monitoring and control technologies are incorporated into NERC standards.

Innovations are also not included in planning requirements even when they might serve the planning objectives better than other options. When transmission planners consider reliability or efficiency needs, they almost never consider the technologies discussed here. The grey bars in the chart below show how rarely advanced technologies make it into transmission plans in the California ISO. Other RTOs and ISOs provide less information so it is hard to tell whether they are even considered.



V. FERC Authority and Policies to Date

FERC regulates investor-owned transmission providers outside of the ERCOT system of Texas and outside of transmission that is part of bundled retail service. That means it sets the rates, terms, and conditions of transmission service, investment, and operation for transmission facilities in PJM, NYISO, ISO-NE, MISO, SPP, and CAISO. This scope of FERC's authority is relatively new; when RTOs and ISOs were created in the late 1990s and early 2000s the transmission facilities transferred from state to federal jurisdiction. In a historical sense FERC is still in the early stages of determining how best to regulate the sector.

FERC has long recognized the room for improvement in the cost-of-service regulation model it employs. The Commission issued a Policy Statement on Incentive Regulation in 1992, applying to pipelines as well as electricity, stating "in order to enhance productive efficiency in non-competitive markets, the Commission will allow regulated utilities to propose incentive rate mechanisms as alternatives to traditional cost-of-service regulation."[19]

Later, in Order No. 2000 performance-based regulation (PBR) was a significant focus. According to the Commission "The vast majority of commenters favor PBR of some form to promote efficient operations by RTOs." It cited prominent economists including Dr. Paul Joskow of MIT who said "It is very important for the Commission to adopt regulatory mechanisms that provide transmission owners and operators with powerful economic incentives to operate transmission networks efficiently…"[20] The Commission concluded, "we believe that PBR, especially if accompanied by explicit and well-designed incentives, may provide significant benefits over traditional forms of cost-of-service regulation."[21] At the same time the Commission recognized the practical challenges: "the Commission should encourage RTOs to consider use of PBR, although we recognize the difficult analytical challenges that RTOs will face."

Five years later Congress recognized the importance of incentives in the Energy Policy Act of 2005. Section 219 provided for incentives to "encourage deployment of transmission technologies and other measures to increase the capacity *and efficiency* of existing transmission facilities *and improve the operation* of the facilities." (italics added) This provision gave the Commission clear authority to review, alter, or amend rates in order to improve the incentives, as long as they otherwise meet the legal requirements of being just, reasonable, and not unduly discriminatory or preferential.

When FERC implemented EPAct 2005 in Order No. 679 provisions, very little focus was either raised or addressed on the efficiency or operations of existing facilities. Almost all of the attention was focused on grid expansion incentives, and Return on Equity levels to encourage expansion. Performance-based regulation was discussed but commenters suggested the difficulty in "determining appropriate performance measures or benchmarks"[22] and concluded it would be premature to adopt it at that time.

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[19] 61 FERC ¶ 61,168, October 1992.
http://assets.complianceexpert.com/fileserver/file/26493/filename/Policy%20Statement%20on%20Incentive%20Regulation,%2061%20FERC%20%C2%B661,168%20(1992)%20(October%201992).pdf

[20] Order No. 2000 p. 538.
[21] Order No. 2000, December 1999, 89 FERC 61,285, pp538-541.
[22] FERC Order 679, page 139.

After five years of experience with Order No. 679 in place the Commission undertook a review. In a Notice of Inquiry the Commission observed "To date, the vast majority of applications for transmission incentives filed with the Commission have focused on the enlargement of facilities, including construction of new transmission facilities. Few applications have focused on the improvement, maintenance, and operations of transmission facilities or on increasing their capacity or efficiency… For example, this could include software improvements that enhance scheduling and dispatch or investment in tools to enhance self-healing grid capabilities or improved situational awareness."[23]

The inquiry led to a policy statement which clarified its incentive policy for grid expansion related issues, but not grid utilization. It acknowledged once again the issue: "Investments in the following types of transmission projects may face the types of risks and challenges that may warrant an incentive ROE based on the project's risks and challenges that are not either already accounted for in the applicant's base ROE or could be addressed through risk-reducing incentives: …3. projects that apply new technologies to facilitate more efficient and reliable usage and operation of existing or new facilities…Examples of projects that meet this description include those that create additional incremental capacity without significant construction (e.g., through the use of dynamic line rating), that allow for more efficient balancing of variable energy resources, and/or that provide increased grid stability. In addition, the Commission is concerned that its current practice of granting incentive ROEs and risk-reducing incentives may not be effectively encouraging the deployment of new technologies or the employment of practices that provide demonstrated benefits to consumers. Accordingly, the Commission remains open to alternative incentive proposals aimed at supporting projects that achieve these ends." The Commission didn't address that gap. It only changed its policy from considering stand-alone advanced technology filings to one where advanced technologies would be considered only as part of the overall nexus of risk to requested rate of return.

Thus under current regulations there is only an incentive for advanced technology if it is part of a grid expansion proposal, and if a demonstration can be made that there is some risk. That is not particularly useful for the network optimization technologies discussed here. They are not risky and as such it would be hard to demonstrate that they are.

After these multiple iterations of review, despite multiple statements by the Commission acknowledging the issue, there is very little incentive to improve the operations of existing facilities.

VI. What FERC Can Do to Remove Barriers for Advanced Technologies

The Commission plays a key role in removing each of the barriers described above. As the economic and reliability regulator, it has authority to change the incentives, planning requirements, and reliability standards and practices. We recommend the following actions:

Informal encouragement

The Commission can promote practices even without taking formal action. When the industry knows the Commission is "watching" and cares about an issue, companies put their best minds on it. That would help a great deal. There is nothing preventing transmission owners from widely deploying these

[23] Promoting Transmission Investment Through Pricing Reform, May 2011, RM11-26, p.13.

technologies, other than their limited interests in doing so. The costs of deploying these technologies are extremely low compared to grid expansion so opposition from wholesale customers should be minimal (in fact, customers would likely support these initiatives). The Commission can jump-start action by the whole transmission industry and associated experts by announcing a **Technical Conference**, spreading information about the opportunities in innovation and technology, and requesting information from stakeholders on any real or perceived barriers to implementation. The issue is overdue for Commission attention yet there is a foundation of FERC staff experience and recent analysis.

The Commission can also recruit the support of RTOs and ISOs. The mission of RTOs is to increase the efficiency and reliable operation of the bulk power system. They use advanced Energy Management Systems, auction methods, and dispatch algorithms, all for the purpose of efficient use of the generation fleet in the region. Efficiency of the transmission system should be an equal or greater focus given the greater authority the Commission has over transmission than it has over generation. RTOs can help overcome the natural risk aversion of transmission owners to evaluate and provide their expertise regarding the safety and reliability of these systems. They can establish stakeholder processes to promote and work through any challenges associated with system deployment, as SPP and PJM have begun to do.

Entertain Proposals

The Commission could express its interest in receiving tariff and incentive proposals from transmission owners, RTOs and ISOs. Following a technical conference with oral and written testimony, the Commission could issue a short policy statement encouraging new approaches. It could cite its own previous observations outlined above and note that it has ample authority to entertain new ideas as long as they meet FERC's other legal principles and policies.

Evaluate Performance Metrics

A policy statement could mention performance metrics such as congestion reduction which could be factored into revenue requirements. The Commission could undertake an exploration of which specific metrics or combinations of metrics might be useful. Performance-based regulation in other industries often uses a combination of metrics and indicators in order to reward good performers on matters that are under the control of the regulated entity while holding them harmless from the impacts of factors outside of their control. In this case the reduction of congestion is something the transmission owner can significantly influence, but there are factors such as natural gas prices that can influence congestion costs that are out of its control. So a gas price adjustment could be included. The Commission could evaluate and entertain proposals and analysis of such an approach.

The Commission could entertain proposals on making beneficial operating cost activities equally profitable as capital expenditures. This equalization would reduce the bias towards capital investment and provide greater opportunity for activities that involve operations.

As the Commission reviews its policies on Return on Equity, it could do so with an eye towards promoting operational efficiency. Higher ROEs should be awarded for activities that benefit customers; deploying efficiency improving technologies that reduce costly congestion is one such activity.

Provide Operations Guidance

While transmission operations encompass multiple activities in different timeframes, a significant share of congestion costs can be traced to inefficient transmission outage scheduling and coordination practices. When a transmission facility is out of service, e.g., for maintenance reasons, the network tends to have less capacity and therefore congestion occurs more often under these conditions. Transmission outage coordination is under the purview of RTOs, which approve (or deny) transmission outage requests made by transmission owners. In general, the approval is based on reliability impacts only, although congestion impacts are sometimes considered as well. For example, PJM does not consider market impacts for outage requests submitted "on time," but would deny an outage that increases congestion if that request was submitted "late."[24] In addition, once an outage takes place, except for very specific situations[25] the transmission owner or the RTO do not bear the costs of congestion caused by the outage and as such they have limited incentives to reduce the economic impacts of the outages.

The Commission could require RTOs to use every practical mean to minimize the impacts of planned outages, including the use of network optimization methods and advanced transmission technologies.

Provide Planning Guidance

As discussed above, most RTO planning does not consider network optimization options in their process. FERC has been reviewing its transmission planning policies under Order No. 1000. This issue could be incorporated into that proceeding or any other effort where FERC provides guidance on transmission planning. FERC could require that network optimization methods be considered in transmission planning. Commenters in FERC's Order 1000 proceeding made some specific suggestions for RTO planning:[26]

- "The Commission should request and make publicly available information from regional and utility planners on the frequency with which various advanced transmission technologies are being included in transmission project proposals, selected in competitive solicitations, and deployed on regional networks.
- The Commission should request and make publicly available information from transmission planners and RTOs as to whether and how various advanced transmission technologies are currently being taken into consideration in regional planning scenarios and analyses and also in competitive solicitations and evaluations.
- Consistent with information collected from planners and RTOs, the Commission should encourage regional planners to consider advanced transmission technologies in every phase of their analysis, planning, and in competitive transmission solicitations and evaluations. The Commission should work with planners to develop scenarios that incorporate increased levels of advanced transmission technology deployment and evaluate their benefits and costs."

FERC Interconnection Rulemaking

[24] PJM Manual 3, Transmission Operations, Revision 52, Effective Date: 12/22/2017, pages 64 and 65.
[25] *Ibid,* section 4.2.9.1, page 70. In PJM, a transmission owner may elect to pay for the congestion costs associated to a "late" outage request, to avoid a transmission outage denial from PJM.
[26] Comments of Americans for a Clean Energy Grid, CTC Global, Lindsey Manufacturing, and Smart Wires in AD16-18.

The interconnection NOPR is before the Commission awaiting finalization. The Commission could require that when studies are performed and network upgrade costs are assigned to interconnection customers, advanced transmission technologies be considered. Interconnection customers would benefit from a wider range of options which may include lower-cost, best-efforts solutions leveraging advanced transmission technologies. Such a request was made by the Dynamic Line Rating/Transmission Capacity Forecasting Coalition in the docket.[27]

Reliability Guidance

NERC, and FERC which oversees NERC, can review the reliability and resilience improvements from network optimization methods. As noted above, while most of the time lines are rated too conservatively, other times they are not rated conservatively enough, taking a reliability risk. Technologies such as DLR will improve reliability by increasing overall capacity and providing ratings based on actual conditions rather than static assumptions. In addition, under current operating practice the grid is frequently subject to transmission element overloads. These reliability violations could be avoided or significantly relieved using advanced transmission technologies. NERC has in other instances encouraged transmission owners to undertake certain practices. If it finds reliability improvement opportunities, it could communicate that to the industry.

NERC and FERC could also review reliability rules to make sure they are not serving as barriers to the deployment of reliability-improving technologies. Specific rules and penalty structures could potentially be modified to allow for reliability-improving technology deployment.

[27] RM17-8 Comments of DLR/TCF Coalition.

Appendix A: Congestion Cost Savings from Advanced Transmission Technologies

Transmission congestion can increase electricity bills paid by American households and businesses. It results from limits on transmission flows from one location and "re-dispatch" of electricity generation such that higher cost generators must be turned on to supply electricity demand.

Congestion costs are likely to rise in the US. It had been on the decline after a significant build-out of transmission capacity from 2009-2015. But there is much less transmission expansion planned in coming years than in the past. Interconnection queues and generation deployment estimates suggest continuing development of generation resources in constrained areas. The retirement of some generation in certain areas may create some space on the grid. But the combination of reduced transmission investment and growing remote generation development will likely cause congestion to grow.

Determination of congestion costs and the savings possible from advanced transmission technologies requires detailed region-by-region study. The purpose of this short analysis is to provide an initial rough estimate.

The analysis below indicates that a combination of advanced power flow control, topology optimization, and dynamic line ratings would save American households and businesses around $20 billion over 10 years.

I. Congestion Costs in the US

Congestion costs are known in two-thirds of the country, and not well known in the other third. Where it is known is where there is a Regional Transmission Organization (RTO) or Independent System Operator (ISO) because they transparently price and post congestion. Other efforts to calculate annual transmission congestion cost such as the Congressionally mandated National Electric Transmission Congestion Study[28] by the Department of Energy faced the same challenge in calculating national transmission congestion cost.

If one assumes that congestion outside of RTOs is similar in magnitude to congestion inside, then one can extrapolate from the known two-thirds of the country to the other third of the country. That method is employed here.

Congestion costs in the transparent markets in the country for the most recent year in which all the data are available (2016) are shown in Table 1 below. They total $3.91 billion.

[28] https://www.energy.gov/oe/services/electricity-policy-coordination-and-implementation/transmission-planning/national-2

Table 1: 2016 Annual Transmission Congestion Cost, Transparent Markets

Region	2016 congestion cost ($ million)
CAISO	142
ERCOT	497
ISO-NE	39
MISO	1,400
NYISO	529
PJM	1,024
SPP	280
Total	3,911

Sources shown below.

To extrapolate from the transparent regions to the full country we need to know what portion of the country is covered by transparent markets. Sixty six percent of the load in the country is covered by RTOs, estimated by comparing the percent of peak loads, using the data below in the Market Size Comparison section. Dividing $3.911 billion by 0.66 yields $5,952 billion. Thus we estimate annual US transmission congestion cost to be approximately **$6 billion per year**.

II. Congestion Cost Reduction from Transmission Technologies

There are a few indicators of how much of the $6 billion could be reduced through advanced transmission technology. The market monitor for MISO estimated that "as much as $155 million in production costs savings could be achieved by fully adopting temperature-adjusted, short-term emergency ratings throughout MISO."[29] MISO had $1.4 billion in congestion as shown above, so these savings are a little over 10 percent of total congestion.

An Oncor study and pilot project found that transmission capacity could be increased by 30-70 percent using Dynamic Line Ratings.[30] The New York Power Authority pilot project showed capacities increased 30-44 percent above static ratings.[31] Clearly these pilots indicate significant economic savings though the amount would depend on how much out-of-merit dispatch occurs at the times when capacity increased, and that was not quantified.

One study of transmission topology optimization found 30-50 percent reduction in congestion costs in PJM.[32] Another study in the UK found savings of between GBP 14 and 40 million out of an annual congestion cost of GBP 340 million, so the relative savings are on the order of ten percent.[33]

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[29] https://www.misoenergy.org/Library/Repository/Report/IMM/2016%20State%20of%20the%20Market%20Report.pdf

[30] https://www.smartgrid.gov/files/SGDP_Transmission_DLR_Topical_Report_04-25-14_FINAL.pdf p. vi.

[31] https://www.smartgrid.gov/files/SGDP_Transmission_DLR_Topical_Report_04-25-14_FINAL.pdf p. vi.

[32] http://newgridinc.com/wp-content/uploads/2016/06/PRuiz-FERCTechConf-28Jun2016.pdf slide 15.

A combination of the technologies that increase grid utilization would increase the total savings.

With savings of 10 percent from one technology and over 30 percent from another, and adding these technologies together along with others, it seems safe to estimate that savings from the suite of technologies could be on the order of 1/3 of congestion costs. With annual congestion costs around $6 billion/year, that would be $2 billion/year in savings. So over a 10 year period, savings could be **$20 billion**.

Studies of this potential would be needed to provide a more robust estimate. The studies should be done for each region, and take into account the shape of the dispatch curve and grid configuration.

III. Market size comparison for use in extrapolating from transparent markets to the US

To compare the size of the transparent markets to the non-transparent markets, in order to extrapolate, these data were used:

Region	2015 peak load (GW)
CAISO	45
ERCOT	70
ISO-NE	24
MISO	126
NYISO	33
PJM	143
SPP	45
US	741
% covered	66%

Sources shown below

The seven ISO/RTO regions' peak load is 66% of the total US peak load. One could also make this comparison based on annual energy.

IV. 2016 Congestion cost sources:

MISO https://www.potomaceconomics.com/wp-content/uploads/2017/06/2016-SOM_Report_Final_6-30-17.pdf, p. x.

SPP https://www.spp.org/documents/53549/spp_mmu_asom_2016.pdf, p.6.

ISO-NE https://www.iso-ne.com/static-assets/documents/2017/05/annual_markets_report_2016.pdf, p. 90.

NYISO http://www.nyiso.com/public/webdocs/markets_operations/documents/Studies_and_Reports/Reports/Market_Monit
10-2017.pdf, p. 20.

[33] http://www.smarternetworks.org/NIA_PEA_PDF/NIA_NGET0169_CL_4458.pdf page 3.

CAISO http://www.caiso.com/Documents/2016AnnualReportonMarketIssuesandPerformance.pdf, p. 12

CAISO intertie http://www.caiso.com/Documents/2016AnnualReportonMarketIssuesandPerformance.pdf, p.178

PJM http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2016/2016-som-pjm-sec11.pdf, p. 1.

ERCOT https://www.potomaceconomics.com/wp-content/uploads/2017/06/2016-ERCOT-State-of-the-Market-Report.pdf, p. i.

V. Peak Load Sources

US https://www.statista.com/statistics/187322/us-electric-peak-load-since-1990/

PJM http://www.pjm.com/~/media/planning/res-adeq/load-forecast/summer-2015-pjm-5cps-and-w-n-zonal-peaks.ashx

CAISO http://www.caiso.com/Documents/2015AnnualReportonMarketIssuesandPerformance.pdf p. 26

NYISO http://www.nyiso.com/public/webdocs/markets_operations/services/planning/Documents_and_Resources/Planning_D p. 11

ISO-NE https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/net-ener-peak-load

MISO https://www.misoenergy.org/Library/Repository/Study/Seasonal%20Assessments/2016%20Summer%20Resource%20A

ERCOT http://www.ercot.com/content/wcm/lists/114580/2017_Long-Term_Hourly_Peak_Demand_and_Energy_Forecast.pdf p

SPP https://www.spp.org/documents/41597/spp_mmu_state_of_the_market_report_2015.pdf, p.22.