Technical Performance Report

Fall 2011

Oncor Electric Delivery Smart Grid Program

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Company Name: Oncor Electric Delivery Company

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Acknowledgement & Disclaimer

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1. Scope

This document represents a Technical Performance Report for the Oncor Electric Delivery ("Oncor") Smart Grid Demonstration Program ("SGDP"). This SGDP program applies real-time sensing instrumentation that will monitor the line conductor tension from several transmission lines. This information through an algorithm is used to calculate the Dynamic Line Rating ("DLR") which represents the maximum line capacity, i.e., maximum power transfer capacity of the transmission line, based on ambient weather conditions and the physical location of the transmission lines. This information when incorporated into a utility's transmission management system is used to dynamically rate transmission circuits and supplement their transfer capacities. This Project is designed to demonstrate the effective use of dynamic line ratings to reduce transmission grid congestion and will estimate the dollar benefit to the wholesale electricity market based on data collected during the Project.

Oncor is the sixth largest transmission and distribution ("T&D") utility in the U.S. and the largest in Texas with approximately three million points of delivery in a service area covering north-central, eastern, and western parts of Texas. Oncor is a transmission service provider ("TSP") within the transmission region controlled by the Electric Reliability Council of Texas ("ERCOT"). Within ERCOT there are numerous transmission paths that are at times considered to have Commercially Significant Constraint ("CSC"), i.e., there is insufficient transmission capacity along the given path to efficiently transmit the power between generation source and load demand locations.

Oncor installed and commissioned the DLR technology to provide dynamic ratings and perform utility studies on eight transmission circuits on its system. Those eight circuits are located in Bell, Bosque, Falls, Hill, McLennan, and Williamson Counties in central Texas and are part of the North to South Commercially Significant Constraint Path as designated by the ERCOT in the 2008-2009 timeframe.

The following sets forth the objectives, benefits, key asset deployment milestones, associated data collection, aggregation and analysis methods, monetary investments, baseline data, market place innovation, and collaboration/interaction with the DOE necessary to accomplish Oncor's fully integrated Smart Grid project.

1.1 Introduction to Oncor Electric Delivery Company

Oncor is within the ERCOT region in which retail competition for customers of investor-owned utilities was implemented on January 1, 2002. The market structure for ERCOT required vertically integrated utilities to separate their business functions into three distinct companies: a power generation company, a T&D utility, and a retail electric provider ("REP"). T&D utilities remain fully regulated by the Public Utility Commission of Texas ("PUCT"), with rates set on a cost-of-service basis and open access to all buyers and sellers of electricity. The rates of power generation companies and REPs are not regulated. Oncor provides T&D delivery services to REPs who bundle the commodity and T&D costs in their customer invoices. Oncor provides electricity delivery and measurement services and does not sell electricity.

As a T&D utility within ERCOT, Oncor delivers energy to the REPs who have direct relations with the end use customers. Another facet of this three-part electric provider system in ERCOT is that the actual costs of the transmission congestion constraint and relief are not defined or maintained by Oncor. As an open access provider, Oncor's role is strictly to efficiently and reliably provide energy deliver service between any generation entity, wholesaler and any authorized power retail service within Texas. Oncor is compensated by a regulated return based on its overall capability to deliver electricity.

Oncor's service territory is illustrated in Figure 1. You can envision the context of Oncor's service area as part of ERCOT by comparing Figure 1 and Figure 2. The size and extent of Oncor's service territory and operating statistics are provided in Table 1.

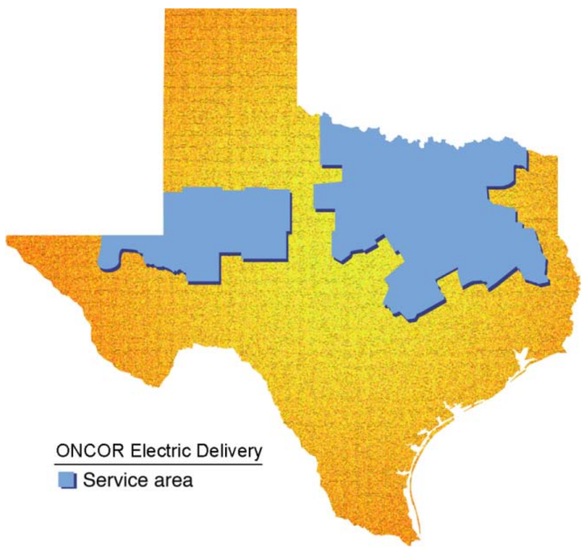

Figure 1 - Oncor Service Area

Figure 2 - ERCOT Region

Table 1 - Oncor Electric Delivery Service Territory Operating Facts

Oncor's Service Territory as of 12/2010	
Total number of customers:	
Residential **Commercial** **Industrial**	3,160,851
Peak load:	
Summer	24,629 MW
Total MWh sales	
Residential **Commercial** **Industrial**	109,323,278 MWh
Total number of substations	705
Total number of distribution feeders	102,728
Total miles of distribution line	96,477
Total number of transmission substations	278
Total number of transmission circuits	725
Total miles of transmission line	15,304

1.2 Project Overview

The Oncor DLR Project is a Regional Demonstration Project. The Project includes the instrumentation of eight transmission lines in a section of the system grid where Commercially Significant Constraint ("CSC") existed when the project was proposed, see Figure 3. The CSCs inhibit transfer of electric power from the generation sources to the area of load demand. Transmission lines are operated at a line rating that reflects the allowable transfer capacity across a given line segment, based on mandated vertical clearances to ground and other objects for safety and operating considerations. When the required transfer capacity across a path exceeds this limit or there is a risk of exceeding this limit with the outage of a generation source or another grid asset, the system operators must redispatch the generation mix such that the allowable transfer capacity across the grid does not exceed the posted allowable ratings. The risk noted in the previous sentence associated with exceeding line ratings if another outage or operating event occurs is known in the industry as planning/operating for an n-1 contingency.

The Oncor SGDP Project will install instrumentation which monitors the tension of the conductors in real-time. The sensing technology and associated algorithms translate the line tension into the available line rating that can be safely maintained in the line section being monitored. This rating is provided to the system operator's console and the system state estimator model. The real-time dynamic line rating provides increased capacity 90 to 99 % of the time and has the potential for reducing transmission line congestion and allowing the system to operate at optimum levels for a greater proportion of the time. The line capacity is established as a line rating correlating conductor type and size with ambient wind speeds, temperature and solar radiation.

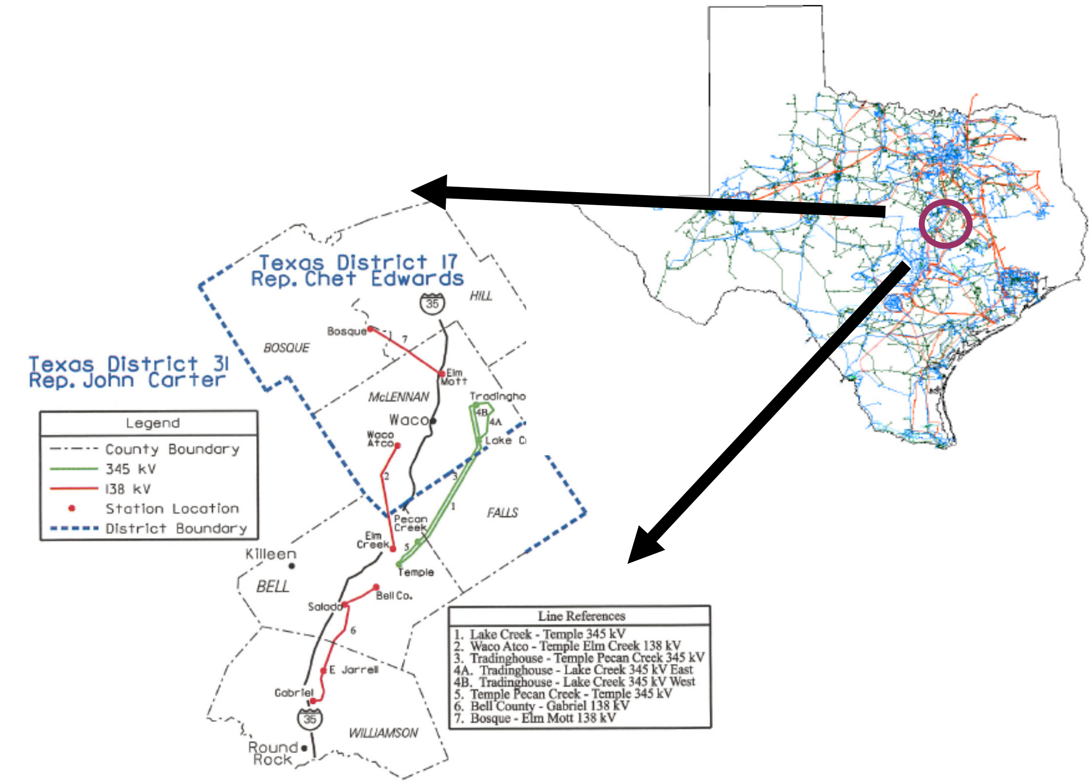

Figure 3 - SGDP Project Map Showing Test Line Locations

During line operation, the conductor transfers current from source to load sink. The line current creates heat within the conductor from joule heating. As Figure 4 illustrates, there is a thermal environment around the conductor that develops heat balance forces increasing the heat of the conductor or removing heat. Heat is caused through the joule heating from the current and absorption of radiant heat from the sun. Countering the influx of heat is the radiation of heat from the conductor and the convection of heat away from the conductor as wind blows past the conductor. The heat balance takes into consideration the ambient temperature, solar radiation level and wind speed and direction to drive the conductor to its operating temperature.

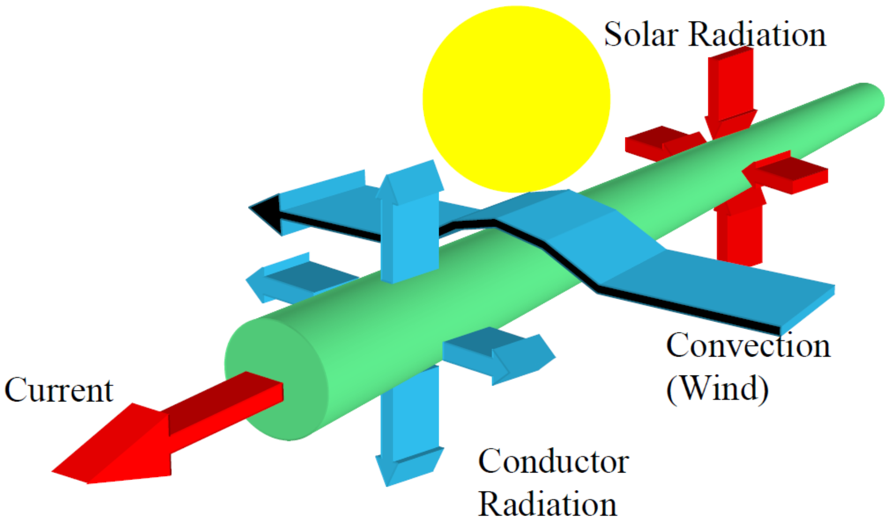

Figure 4 - Conductor Line Rating Thermal Characterization

Traditionally a fixed set of ambient parameters which have a prescribed probability of occurrence were established as the base rating case for planning and emergency line ratings. ERCOT has allowed its associated transmission providers to utilize an adjusted rating, taking into account the ambient temperature. When the ambient temperature is lower than the assumed static rating ambient temperature, a higher line rating can be applied. However, when the ambient temperature is above the static rating base temperature, the allowable equipment ratings will be lower than the static rating.

The DLR Project is designed to take into account the ambient temperature, the wind blowing across the conductor to cool it and the ambient solar radiation to model the heat balance effect on the conductor. By dynamically adjusting the line ratings, the transmission capacity will be increased the majority of the time allowing more opportunities for optimal utilization of the transmission grid and optimized economic dispatch of the generation.

As Figure 3 illustrates, the DLR Project is concentrated on a small portion of the Oncor transmission grid and an even smaller portion of the ERCOT system. The deployment strategy of the DLR instrumentation and analysis package is an important aspect of determining the accuracy of the dynamic rating model and critical to an accurate prediction of available transmission capacity. The DLR Project will analyze the data obtained during peak winter and summer seasons monitoring periods to develop an appropriate protocol to recommend and guide future application of the DLR technology to other locations where CSCs exist.

1.2.1 Project Objectives

The Oncor DLR Project will install a dense array of instrumentation on the noted transmission line segments to collect the necessary real-time data. The SGDP Project will assess the data recorded and line rating calculations to determine the optimum location for sensing devices to achieve the accurate real-time ratings required for optimal application of DLR technology for system operation. This protocol will be a Project deliverable for application by future DLR Projects throughout the US transmission grid.

The economic impact of the reduction in CSCs will also be computed throughout the Project period to demonstrate the economic benefits of implementing the DLR protocol delivered by this Project. Combined, the protocol and the benefits of congestion relief will be a valuable package for other utilities to optimize their transmission systems and make the grids more efficient.

In short the Project objectives are:

Remove Existing Commercial Significant Constraints which Include:

- Clear Demonstration that DLR technology is Reliable – operate the system using real-time dynamic ratings over the course of several critical peak operating seasons;
- Utility Planners Understand the Cost Structure and Benefits - quantify the increased line capacity for planning and operating the system more efficiently;
- Interoperability with Utility Transmission Management Systems – incorporate the dynamic rating functionality into the system control center's operating protocols so it is transparent to the operators. Assure the integrity and accuracy of the data through Cyber Security assessment.

Economic Objectives

- Quantify economic value of released transmission capacity to market;
- Estimate the savings associated with deferral of rebuilding, reconductoring, or building new circuits to meet transmission requirements;
- Quantify the total costs of implementing an effective DLR program.

Operational Objectives

- Relieve congestion and transmission constraints;
- Gain operational knowledge of DLRs for wide scale deployment;
- Ensure that safety code clearances are not impacted;
- Demonstrate that multiple monitoring units can be integrated into operations;
- Identify/quantify other operational limits that may impact ability to raise ratings.

Demonstration Objectives

- Extrapolate the impact of DLRs on the study's transfer path to entire ERCOT region.
- Determine a methodology to release day-ahead ratings;
- Develop user friendly tools for the operator to manage improved Wide Area Situational Awareness ("WASA").

1.2.2 Project Milestones and Schedule

There are two distinct phases to the project:

- First, the installation and deployment of the DLR instrumentation and validation hardware into the field, development of the software interfaces and modifications to the Oncor Electric Management System (EMS), and the calibration of the systems to bring them online to stream DLR data to the operating environment; and
- Second, the application of the DLR data in the operating environment and the technical assessment of the impact of DLR on the availability of transmission line capacity, the accuracy and optimization of the DLR deployment protocol , an assessment of the interoperability and cyber security capabilities, and the impact on congestion relief from an economic aspect and environmental aspect.

With regard to the installation, deployment and commissioning of the DLR systems, the primary DLR instrumentation packages was scheduled for the fall of 2010. The software enhancements to the Oncor EMS system to integrate the DLR ratings into the operating environment were scheduled for the spring of 2011. Installation of secondary line status hardware to validate the accuracy and reliability of the primary DLR systems was scheduled for the spring of 2011. Go-Live DLR system streaming of DLR data to the Oncor and ERCOT operating environment was scheduled for the summer of 2011. Refer to Table 2.

The Interoperability and Cyber Security (I&CS) Plan was completed in the spring of 2011 and the study to fully assess the DLR technology for I&CS was scheduled for execution through 2011. The quantification of the accuracy, reliability, and economic potential impacts of the DLR technology are scheduled to initiate after the system is operating through the completion of the project operating window ending December 2012.

1.3 Project Benefits

Oncor's economic benefits from this Project are summarized as:

1.3.1 Improved Management of Transmission Lines

The Oncor DLR demonstration is significant when compared to current practices because this Project will allow future utilities faced with constrained or heavily loaded transmission lines to be better able to manage those lines, i.e., increase the transfer capacity of the line based on real-time conditions rather than static contingent parameters. In the current operating environment, utilities have the ability to accurately measure their load, in real time, but they have limited means to know the capacity, in real-time, of one of their most valuable assets – the transmission grid.

Table 2 - Project Milestones and Schedule

Date	Milestone
04/30/2010	Initial DLR Installation
09/16/2010	Design Installation Plan/Material Procurement
01/31/2011	Terminal Upgrades
03/25/2011	Complete DLR Installation
03/25/2011	Installation of Sag Monitors
03/28/2013	Project Studies: Reported Quarterly • Analysis of DLR real-time constraint release • Sag studies – alternative DLR technology confirmation • Economic Trade Space Analysis • Cyber Security Study • Technology Deployment protocol
06/28/2013	Complete Project Documentation

1.3.2 Enable Further Deployment of DLR Technology

Oncor will document the findings from this Project and make this knowledge available for wider deployment within Oncor's transmission system, the ERCOT region, and throughout the nation as part of the national Smart Grid initiative.

Through this Project, the DLR technology will be demonstrated on the selected region and set of transmission circuits. The following key parameters will be demonstrated and documented in order to ensure easier and more fluid wider deployment at the regional and national level:

- Installation procedures that demonstrate how installation can be streamlined including potential improvements on the assembly itself or the installation practices and methodology;

- Optimizing the number of monitors required to accurately rate the transmission line, depending on dead-end and insulator type;
- Training for installation crews on effective installation practices;
- Development of a "Best Practices" manual for future installations; and
- Evaluating current calibration techniques with a view to improve productivity while maintaining and improving on accuracy.

Viability and practicality will be two of the key objectives as described above. More specifically, the viability of "knowing" one's true transmission capacity in real-time is almost axiomatic. The Project will demonstrate this concept.

More importantly, the Project will demonstrate and quantify the benefits of having this additional and deterministic knowledge of the true circuit capacity and how it can be utilized to optimize the entire transmission system for energy delivery. For instance, Oncor anticipates that dynamic line ratings will expose the next operational limit on the grid. Oncor will then be in a much better position to perform economic analysis as to the next optimum investment.

1.3.3 Economic Value of Capacity Released by Dynamic Line Ratings

The transmission grid is made up of multiple paths. Each path consists of multiple transmission circuits that when combined form the route along which power flows from generation sources to load sinks. A path is described as constrained or congested when the amount of power that the market wishes to move from generator to load is greater than the power transfer capacity (rating) of the path. That transfer capacity (rating) has traditionally been limited to a fixed (static) value based on worst case weather assumptions (high ambient temperature, full solar radiation, zero or very little wind) designed to protect individual transmission circuits from overheating and sagging too close to the ground. The worse case weather assumptions rarely occur and thus the transmission circuits are limited to an artificially low capacity without better insight into actual conditions along the transmission lines. DLR technologies account for the actual weather conditions and release the true capacity of the transmission circuits and the path.

When the transmission grid's capacity is unconstrained and consumers have full access to the lowest cost generation sources, a competitive market determines the price of electricity. When the grid's capacity is constrained (congested), access to the lowest cost power is limited and consumers must purchase power from higher cost generation sources that have access to transmission line capacity to deliver the power to the load location.

The cost of congestion can be high. During the month of June 2009, a problem with generation in South Texas caused an imbalance within the grid and placed a high demand on one of the circuits to be monitored during this Project. The congestion charges on that line totaled $1,352,966 for the month.

Projecting an exact economic value associated with a reduction in congestion costs that will be achieved with dynamic line ratings is difficult since future meteorological conditions and load flows will not be known with certainty until they occur. However, a sound estimate can be made by examining the economic impact of congestion events that occurred and an adjusted line performance with increased line capacity through DLR and its ability to mitigate the congestion cost. Examining these mitigated costs for several time periods in different seasons and grid conditions will provide an overall estimate for congestion relief through DLR.

Additional economic benefits can be realized through the deferment of capital expenditures when DLR's increased capacity and response to ambient conditions provides a sufficient margin to safely and economically operate the transmission line. Lines with congestion issues will be analyzed to determine the economic advantages of various upgrade alternatives versus DLR capacity.

1.3.4 Technology Advancements of Dynamic Line Ratings

The technical benefits of this SGDP project have direct relations to the interoperability and cyber security issues addressed in this document, including:

1. to validate the technical accuracy and capability of DLR to provide the grid operations with timely and accurate conditional data and capabilities of the transmission line elements;
2. to provide the documentation of consistency, security and accuracy of the real-time data to allow operation decisions to be made to optimize the grid operations and reduce operating and delivery cost of energy; and
3. to provide documentation outlining the protocol that can be applied by Oncor, ERCOT and other transmission grid systems to implement additional DLR technologies within their systems to mitigate transmission congestion and provide a more open, dynamic and secure grid.

Reliable dynamic line ratings provide the means to know the true transfer capacity of the grid in real time. The system conditions or state required to make these adjustments is derived from real-time data measured at remote locations on the transmission line away from the control center or substation measurement environment. That data must be transmitted to some entry point into the grid management system for delivery to an algorithm processing server, and then fed to grid operating systems and personnel for application in the operating displays and technology employed by the grid's system operator. Figure 5 illustrates the DLR system configuration identifying the three zones of activity: Remote (Transmission Line), Utility Entre (Substation) and the Grid Operations (Control Center).

System state conditional data is obtained at the CAT-1™ remote monitors located on structures of the transmission line. That data is transmitted via radio frequency to a substation location equipped with a CATMaster™ unit. The data is then routed through the utility RTU and SCADA system to the control center's EMS/SCADA master unit and the IntelliCAT™ server. The IntelliCAT™ server is where the data is processed using proprietary software to calculate the real-time dynamic rating. The rating is then transmitted back to the EMS system where it is posted for operations. The I&CS Plan will address the CAT-1™ systems, the CATMaster™, and the interface between those system. The SCADA system, its interface, and the EMS system reside within the Oncor security network and will not be assessed.

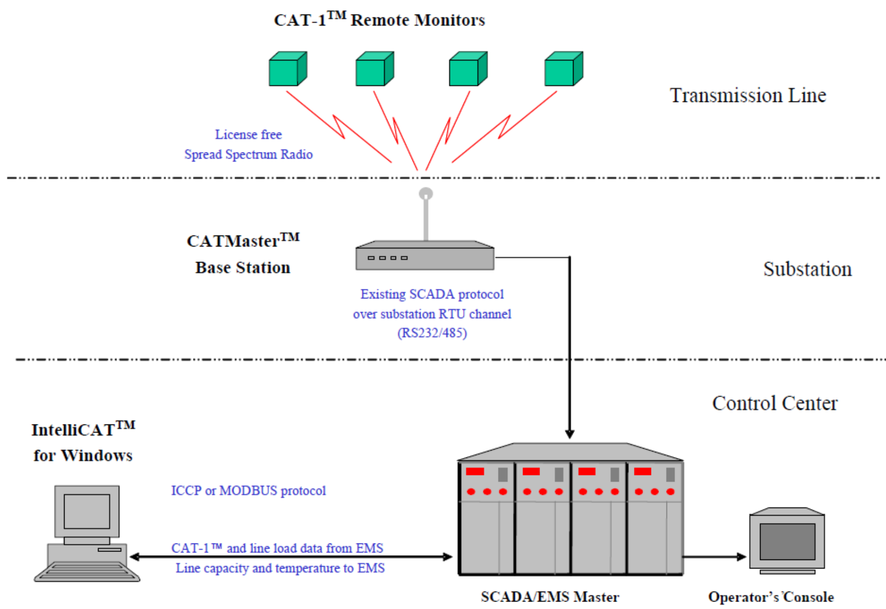

Figure 5 - DLR System Description

1.3.5 Stakeholder Interaction During Project

There are several Oncor internal and external stakeholders that have interest in the project from a commitment of participation basis and from realizing beneficial impacts. Their involvement will be maintained and encouraged as the project evolves.

For example, the previous discussions identified the need to develop a relationship with ERCOT to open a line of communication and information exchange that will provide the Project with specific event information including where and when congestion occurs on the Oncor lines, what is the level of congestion and the economic impact of congestion events. This relationship is necessary due to the de-regulated electric model within the United States whereby the TSP (Oncor in this case) is only a delivery service providing open access to all generation in the region and all energy marketing entities that sell energy to customers.

Internal to Oncor, the Operations Department is a user of the DLR data stream and their application needs and understanding are critical to project success. The Planning Department is also a stakeholder relative to how the DLR Congestion Relief and increased capacity can be used to optimize the planning process and provide guidance for project definition, project prioritization and capital management. DLR may provide sufficient capacity on an instrumented line to defer its upgrade for several years or longer or defer the construction of a new line.

1.3.6 Interoperability and Cyber Security Approach

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Specific smart grid requirements supported by Oncor's DLR Project and aligned with the DOE Interoperability and Cyber Security are addressed in the following pages.

1.3.6.1 Interoperability

The Oncor DLR demonstration project is significant when compared to current practices because the Project will allow utilities faced with constrained or heavily loaded transmission lines to be better able to manage those lines, i.e., increase the transfer capacity of the line and improve system reliability based on real-time conditions rather than static contingent parameters. In the current operating environment, utilities have the ability to very accurately measure their load, in real time, but they have limited means to know the capacity, the line rating, in real time of one of their most valuable assets – the transmission grid.

The real-time monitoring system and processors must be designed to meet interoperability issues on a broad spectrum of system interfaces that while not unique are open to many application variations of industry standard interfaces and protocols. The technical approach to the interoperability issues of the I&CS Plan include:

1. A summary of the interfaces for information exchange and communication of the real-time data to a point inside the utility's secure information zone.
2. A summary of whether the Project technology is open and capable of interfacing with its own components and the legacy systems of the utility.
3. A summary of mitigation strategy to manage equipment changes and updating and to prevent system failures.

4. A summary of how the Project will support the pertinent emerging NIST protocols.

1.3.6.2 Cyber Security

Cyber Security is critical to the success of the DLR Project as the accuracy of the data is critical to the viability of the transmission grid and the numerous interfaces involved in the collecting of remote real-time data and its delivery to a secure utility network is critical to not only the DLR security but the grid operating security as well. The risks include but are not limited to damaging, interrupting or super-imposing false data into the data recovery stream, interfering or sabotaging the data reduction, or using the DLR system as an entree into the main grid information and control system to provide security and operational issues.

Since this is a demonstration project with a service life of two years, the life-cycle aspect of this project is fairly limited in duration. The work performed during this task will, however, provide a strong foundation for all future enhancements to the DLR technology and to the protocol that future utility applications can use to guide them in their DLR projects. As such it will strengthen the cyber security base of the technology by identifying any current issues and developing mitigation actions to correct and address them.

As part of the proof of concept deliverable, the thorough execution of this Interoperability and Cyber Security Assessment is intended to complete the requirements and document the optimum implementation and application strategy for DLR projects of the future.

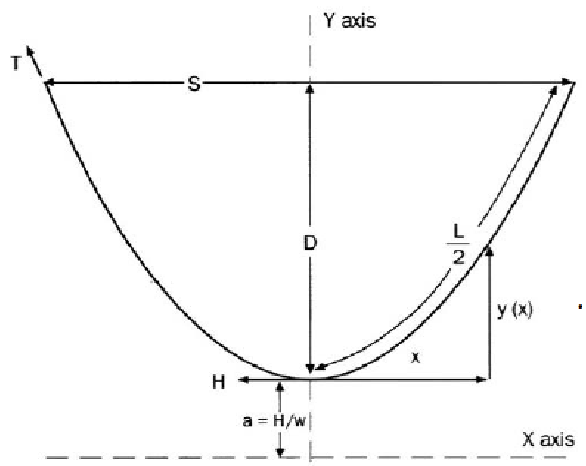
The technical approach to the Cyber Security will include:

1. A summary of the risks, threats and vulnerabilities that the system faces or will face in a service life and mitigation strategies.
2. A summary of the standards and best practices employed for cyber security relevant to the technologies and interfaces applied in the Project.
3. A summary of how this Project will support future applications and development of future DLR installations.

2. Technical Approach

2.1 Conductor Ratings – Heat and Tension

Conductor is suspended in the air according to the physics of the catenary curve which defines the relationship between the conductor's characteristics, the shape of the conductor curve, and the tension in the conductor, see Figure 6. Transmission lines are designed according to a number of anticipated loading conditions from bare wire on low ambient temperature days to ice and wind loaded cold days, and the high temperature maximum load/current carrying conditions.



$$y(x) = \frac{H}{w}\left[\cosh\left(\frac{wx}{H}\right) - 1\right]$$

Figure 6 - Catenary Curve

Figure 7 illustrates a set of typical sag curves for a span. The Dynamic Line Rating ("DLR") Project is focused on the **'Sag@ Max Electrical Load - Tmax'** curve which is directly associated with the Minimum Electrical Clearance which must be maintained at all times to be in compliance with the National Electrical Safety Code ("NESC") . The maximum electric capacity of a transmission line is based on the minimum clearance to ground which dictates the maximum sag allowable in the span to provide adequate safety and operating clearance. That sag is then related to a maximum operating temperature of the conductor. The maximum operating temperature is set by the utility and is typically set at levels like 75°C, 90°C or 125°C. Knowing the maximum sag allowed, the maximum electrical operating load can be determined based on the specific conductor and ambient climatic conditions at the time of loading. Traditionally the climatic conditions for the minimum clearance condition were assumed to be a worst case scenario of minimum wind speed; high ambient temperature and full solar radiation from the sun, e.g., 2 ft/second wind, full sun and ambient temperature of 104°F (40°C).

The DLR Project recognizes that the assumed ambient conditions that static line ratings are based on have a low probability of occurrence concurrent with the period that the maximum load current is required to be carried by the conductors. The DLR Project is designed to determine the actual ambient and conductor parameters along the line to allow the maximum load current to be increased to the point where the Minimum Electrical Clearance is maintained while the current flow is also maximized.

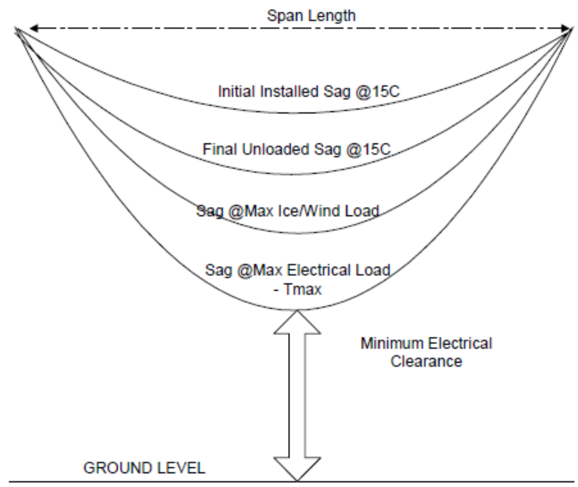


Figure 7 - Typical set of sag curves for a span

The monitoring of the line can be done by measuring the clearance in a span or by measuring the tension in the conductor. From the catenary curve relationship in Figure 6, we know that the sag and tension of the conductor are directly correlated and that measuring the tension in the span can be used to directly calculate the operating parameters in a real-time manner such that the current can be increased to a point where the Minimum Electrical Clearance will not be violated.

The Oncor DLR Project measures the tension in a span section of the transmission line as illustrated in Figure 8. A four span section is illustrated, but the physics apply to any number of spans between deadended structures of the line. The conductor sag and tension are a characteristic of the span section between deadend structures. The intermediate insulator strings swing in either direction along the line to allow the span section to reach an equilibrium condition where the horizontal tension along the span section is uniform. By monitoring this tension, the characteristics of the span section can be monitored rather than a single span or point along the line. This is important from a dynamic line rating standpoint.

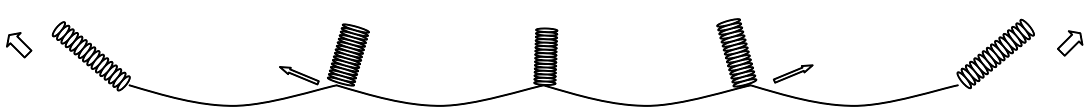


Figure 8 - Tension Monitoring CAT-1 system measures more than one span

The conductor performance characteristics are driven by the electrical loading in the line, i.e., the current, the ambient temperature, the solar radiation and any wind blowing past the conductor. Since the later three variables are spatial in content, i.e., they vary with location along the transmission line; thus the dynamic rating of the line is difficult to measure with a single point reference, i.e., the direct measurement of the temperature of the conductor in one span. One of the concerns about using a point reference as the basis for a dynamic rating is whether one can be sure the worst conditions leading to the minimum clearance exist in the monitored span. By measuring the tension or sag of a section of the line between two deadends, the characteristics of that line section are more accurately determined and a more accurate line rating can be calculated for the ambient conditions.

The following Metrics Derivation shows how the measured line tension is used to derive the various measureable quantities that define the benefits derived from dynamic line rating. i.e., an increased transmission line capacity above the traditional static rating or the currently applied ERCOT temperature adjusted line ratings.

Metrics Derivation

Real-time Measurements:	Line Tension	
	↓	
Real-time Parameters Derived:	Conductor Temperature → Sag → Real-time Ground Clearance	
	↓	
Real-time Line Rating:	MW	[Load to Match Minimum Clearance]
Constraint:	Baseline Rating exceeded by actual loading or n-1 contingency load	
Transmission Constraint Relief:	MW -	Real-time Rating – Baseline Rating
	t -	Duration of increased capacity
	Mw-hr - Mw x t	
	↓	
Economic Relief	$[1]	Mw-hrs x Congestion Shadow Price

2.2 Project Development

When preparing the submission to DOE for this project, Oncor looked at its transmission grid system and operating characteristics and identified a corridor that was experiencing Commercially Significant Constraints (CSCs) due to transmission congestion. At the time, ERCOT, the independent region transmission grid that Oncor operates within, was operated as a Zonal managed system. Figure 9 identifies the four zones within ERCOT and the significant paths in which CSCs were currently identified. Effectively, a CSC is when a number of transmission paths experience sufficient congestion that they constrain economic dispatch of the generation to serve the identified load. For example, the figure shows CSCs between the West and North zones in both directions depending on generation availability

[1] Requires Congestion Shadow Price Cost Data from ERCOT

and load requirements and an export constraint between the South zone and the North zone. This CSC was selected for the DLR instrumentation and validation project. The South – North Zonal congestion historically contributed to the $40,000,000 of incurred congestion costs by the ratepayers per year.

Figure 9 - ERCOT Zonal Layout and Commercially Significant Constraints

The South – North corridor is shown as part of the Oncor grid in Figure 10, this corridor has a main backbone of two circuits of 345 kV transmission and several parallel paths of 138 and 69 kV serving the communities along the I35 corridor between Dallas and Austin, Texas. Five (5) 345 kV circuit sections and three (3) 138 kV transmission lines were selected for instrumentation.

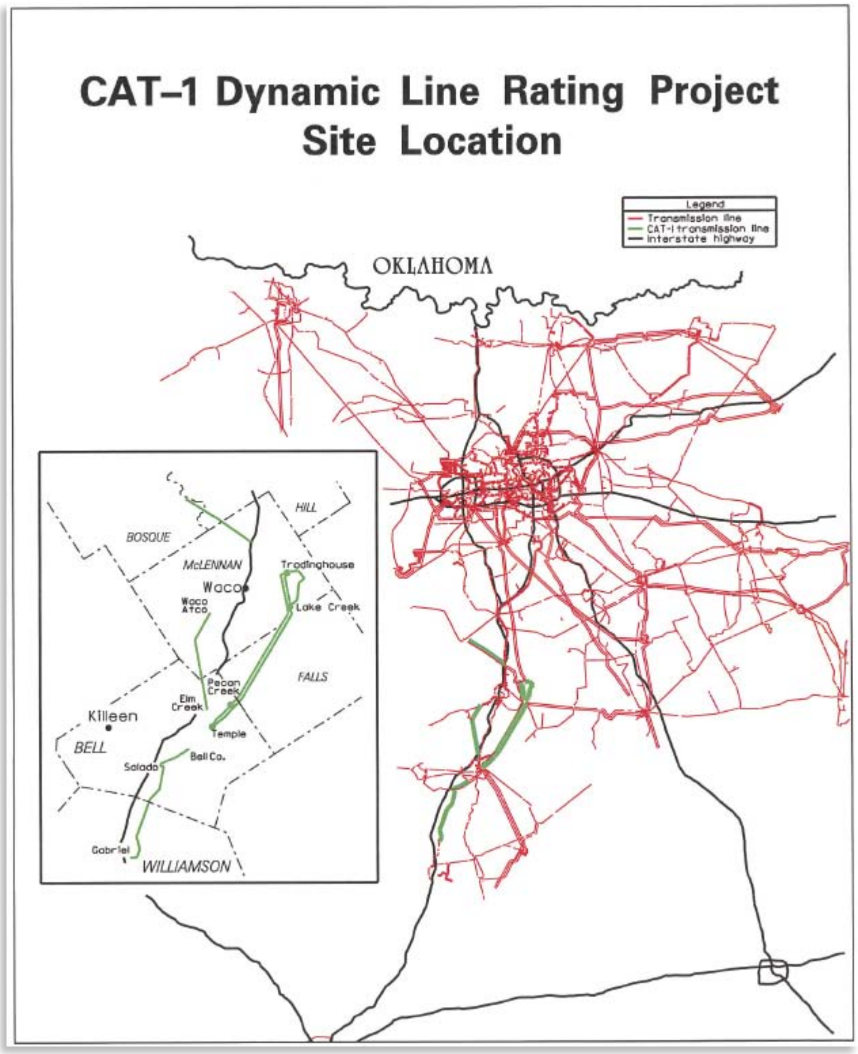


Figure 10 - DLR Project Area Showing Lines Selected for Instrumentation

2.2.1 Nodal versus Zonal Operation

When the project submission was made, accepted and approved, ERCOT was operating as a zonal market. Effective December 1, 2010 ERCOT transitioned to a Nodal Market which significantly changed the way the grid was operated and the way in which congestion was identified and its cost structure. The zones identified in Figure 9 were replaced by over 3,000 nodes associated with each generation unit and every substation and transmission delivery point within ERCOT providing a network shown in simplified terms in Figure 11.

Grid operations changed with this new environment as well, taking advantage of the increased granularity of the system to manage the powerflow and generation dispatch node by node, unit by unit, to provide optimal generation to load matching and system reliability. In the Zonal environment, ERCOT identified generation needs and placed a request for generation within the zone to meet demand. The generation providers within that zone selected the generation unit and brought it on line. The resulting energy costs and congestion impacts were socialized across the zone.

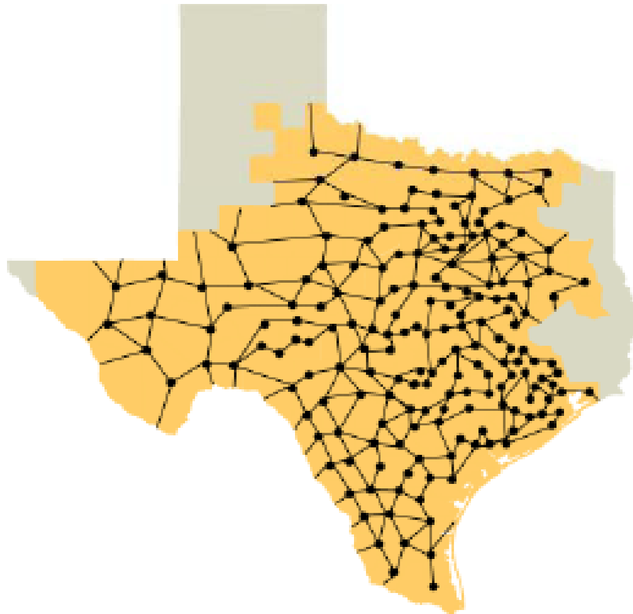


Figure 11 - ERCOT Nodal Configuration

The Nodal market, however, manages the dispatch of generation at the unit level specifying the amount of energy to be generated and the cost to be paid for that generation based on the day-ahead market Energy Offer Curves of the generation unit. The day before the nodal market's operation, the Day-Ahead Market accepts Energy Bids for buying energy at a settlement point and Day-Ahead Energy Offers from energy resources. The offers are three-part and the entity can make the offer as a full three-part, identifying start up costs, a minimum energy offer and an Energy Offer Curve (cost/amount of energy). Using the grid model a co-optimized solution is calculated that matches generation with load considering the transmission element capacities and availabilities and generation offers.

Every 5 minutes during real-time operation a Security-Constrained Economic Dispatch (SCED) run is executed to determine the most economic and reliable generation dispatch to meet load demand and transmission grid status, i.e., consider generation availability, transmission element ratings and transmission element outages. The SCED solution is an optimized calculation of the available transmission delivery system modeled in the Transmission State Estimator to dispatch energy from resources to demand on a node by node basis. The energy offered is based on the Day-Ahead Energy Offers which identify the available sources of energy and the Energy-Offer curves, essentially their cost curve. The State Estimator model may change at any time due to the real-time telemetry that identifies when transmission elements are not available due to a forced or planed outage for maintenance and for energy resources that may be on a forced or planned outage.

Congestion occurs when the transmission grid cannot deliver the power from the desired (lowest cost provider) to the load sink. The congestion can be the result of an actual loadflow limitation where the current would cause the line to operate at a temperature such that the minimum clearance would not be maintained, refer to Figure 7. The congestion may also be due to an n-1 contingency limitation where the next outage of a plant, piece of transmission equipment or transmission line would cause a given line segment to exceed its maximum operating temperature. In either case, the grid operator may be required to redispatch generation to meet the load demand. The nodal market adjusts the Locational Margin Price (LMP) for electric power at each node based on the economic dispatch and congestion costs to produce and deliver the power.

The Nodal market provides much greater control over the grid operations, allowing the ISO to manage generation unit by unit to meet the load demand on the system. By posting an LMP for each node, the actual cost to deliver energy at any given node can be determined. Costs for generation and energy delivery can be directly assigned to the responsible parties. When congestion occurs, it is specifically assigned to the cause of the congestion and the nodal prices reflect that cost and the market settles financially on a node by node basis.

If DLR capability was available on the line(s) that experience congestion and the ambient weather conditions were favorable, the line rating would most likely be higher than the static rating or ambient temperature adjusted rating. With the increased DLR rating the congestion event may have been avoided and congestion cost averted.

In the ERCOT system, the market prices are established in a Day Ahead Market (DAM) where the generation providers identify their availability to generate and their cost of generation delivery curve. ERCOT identifies which resources and providers are required for the next day's operation to meet load forecasts and auxiliary energy services. A day-ahead Reliability Utility Commitment (RUC) system analysis is performed to establish an initial dispatch commitment for the resources. As the day moves into and through real-time, a RUC is performed every 5 minutes as part of the Security-Constrained Economic Dispatch cycle. Based on real-time conditions, the generation resources are given dispatch commitment signals to operate the system as close to optimum as possible. Forced outages of generation and/or transmission equipment may result in congested delivery paths that the SCED resolves to avoid n-1 contingency and stability concerns. The resulting operating signals dispatched at the end of the SCED run include the LMP for each node for the next time interval. If congestion remains on any of the node to node paths, the LMP reflects the cost of congestion and the cost is equivalent to the LMP shadow price times the MW of power delivered.

2.2.2 DLR Instrumentation Design and Deployment

The DLR instrumentation is based on a tension monitoring system developed by The Valley Group a component of NEXANS. The CAT-1 system incorporates a loadcell into the deadend insulator assembly at the end of each stringing section of conductor. The loadcell measures the tension of the conductor and sends a signal to a local processor at the structure. The tension data along with ambient temperature and data on the solar radiation currently affecting the conductor is sent to a nearby substation via radio transmission. At the substation the data is streamed via the RTU and SCADA system of the utility to the system's Energy Management System (EMS). Through the NEXANS algorithms, the data is transformed into a conductor temperature representative of the line section the loadcell is monitoring. From that information, the effects of ambient conditions are calculated and the algorithm calculates what the maximum current capacity would be before the conductor would reach the minimum clearance – maximum sag condition. This revised current flow is the **dynamic line rating** for the line section. By monitoring multiple sections of a transmission line, the minimum dynamic rating can be identified and used for optimum operation of the transmission line.

As mentioned in the technical review of the line rating technology above, the tension or the sag of the conductor/conductor position can be utilized to characterize the line sections line rating behavior. The tension monitoring system was selected for the primary line monitoring technology for this project. The tension monitoring equipment and systems have been deployed by utilities for many years in a variety of line applications. This SGDP deployment is the largest and most aggressive to be installed to bring real-time data to the control room operating environment.

One of the issues associated with proper deployment of a DLR system is the selection of location(s) for monitoring from both a geographic and quantity perspective. For a basic example,

Figure 12 illustrates a simple transmission line layout. There are several types of structures identified at various locations along the line. The Deadend Structure is located at each end of the line, possibly at a substation. A deadend is a location where the conductors are terminated or the direction of the line is sufficiently different such that the conductor is terminated in each direction and attached to a stronger structure to withstand the loads created by the line angle. These are Deadend structures and the conductor is referred to as being deadended or terminated and attached directly to the structure with an insulator string, refer to Figure 13. In this picture, the conductor can be seen terminating directly t the shaft of the pole through an insulator string. The loadcell which measures the tension of the conductor is between the insulator assembly and the pole.

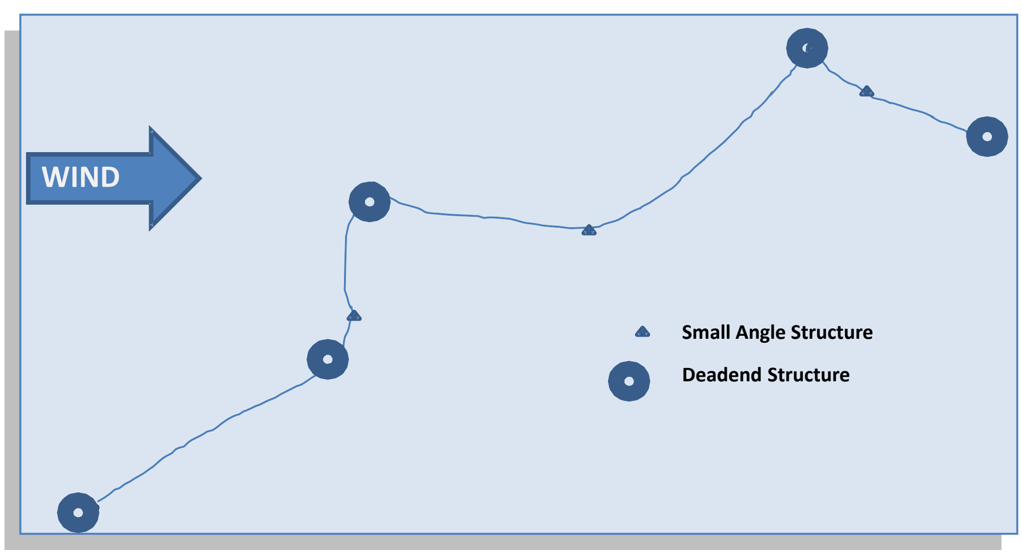


Figure 12 – Simple Transmission Line Layout

The second type of structure identified is a Small Angle Structure. Note that at these locations there is a difference in line orientation but the line angle may be small enough to allow what is called a "running-angle" configuration. This is an attachment similar to but stronger than a suspension point to withstand the increased loads due to the conductor loads associated with the angle in the line. Between these two types of structures, there are many tangent structures that support the conductor off the ground in what is referred to as a suspension attachment, Figure 14. In this illustration, the conductor is supported at the ends of the two insulator assemblies below the arm which is attached to the pole. The suspension attachment is not as "fixed" a position as the deadend position in Figure 13. A suspension insulator can swing longitudinally along the line as the tension of the conductor changes or swing in line with forces imposed on the conductor by wind.

Since wind plays such a significant impact on the DLR rating, the incidence angle of the wind on the line as well as the wind velocity is an important characteristic that must be monitored or considered during monitoring. In Figure 12, the wind is blowing from the left and you can see that the wind has a different incidence angle on many portions of the line from near parallel to the line to perpendicular to the line. When deploying monitoring devices, it is recommended to put monitors in sections between deadends when the line angle or span lengths differ significantly. From a line angle and deadend perspective, the line example is divided into 4 line sections and would require a minimum of four monitoring locations in each section. Note that in the longer middle section there are two lengths that would have different wind incidence angels, one nearly parallel and the second askew to the line. They are separated by a small-angle structure. Due to the incidence angle, another monitor should be added to this section. If there are no other deadends in either of these subsections, one of the tangents should be converted to a deadend configuration to accommodate another monitoring location.

Figure 13 - Deadend Structure

Figure 14 - Suspension Structure

The NEXANS recommendation is that a single loadcell has a reach of 6 to 10 spans in either direction from the device when both sides of a deadend structure are instrumented and no significant angles, i.e., greater than 15 degrees, are encountered or another deadend location. Depending on structure type and line construction, the “reach” will vary… typically, 6-10 spans in each direction, and as many 15 or more spans on lines with longer insulator strings and span lengths. This of course is one of the questions we wish to get a more definitive handle on with the “Optimize Number of Devices” study, as well as the “Sag Verification” study.An objective of this project is to identify a best practices protocol for deploying DLR. So the line sections being monitored have more instrumented locations on them than traditionally applied in the past. An optimization study will be conducted to determine the optimum number of loadcells required to develop accurate line characterization. A sensitivity study of varying combinations of instruments on each line will be used to identify the minimum instrumentation requirement for accurate DLR projections.

Several of the transmission lines monitored for this DLR SGDP are 345 kV lines with lattice towers and no deadend structures between the substations./ Figure 15 depicts the typical 345 kV CAT-1 DLR installation on a tangent structure for this Project. The preferred location is a deadend where the conductor assembly is already in a position to accommodate the loadcell to monitor tension. However, in the case of the 345 kV circuits being monitored, there were no angle structures with deadend assemblies. On the structures selected for instrumentation, "floating deadends" were installed on the lower outboard phase of each circuit. The full structure view of the tangent tower on the left in Figure 15 shows suspension attachments for the conductor on the inboard phases on the bottom crossarms and the top phases. The two outboard phases were converted to "floating deadends".

The top two insets of Figure 15 show a close-up of the floating deadend and the yoke plate assemblies with the loadcell in the left side of the hardware assembly. The vertical insulator is left on the structure and the suspension clamps at the base are replaced with a yoke plate to which the two deadend assemblies for the conductor bundle are attached. The jumper loops below the insulator assemblies and yoke plate carry the current through the floating deadend assembly.

The mid-lower inset shoes the CAT-1 control and communications box with the solar panels for charging the batteries.

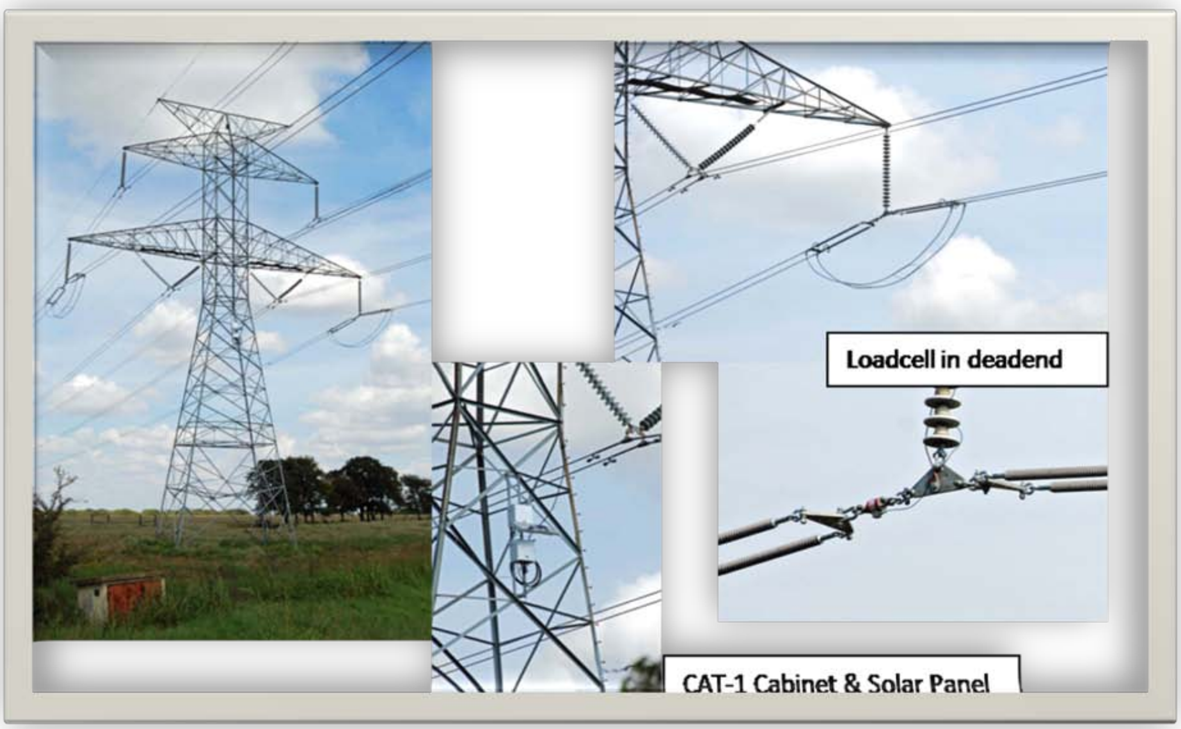


Figure 15 - 345 kV CAT-1 Installation

For the 138 kV installations, several structures were converted from tangent- suspension framing to tangent - deadend configurations to accommodate the loadcell placement. Figure 16 shows the structure framing and details of the deadend with the loadcell and the instrumentation package mounted on the wood pole.

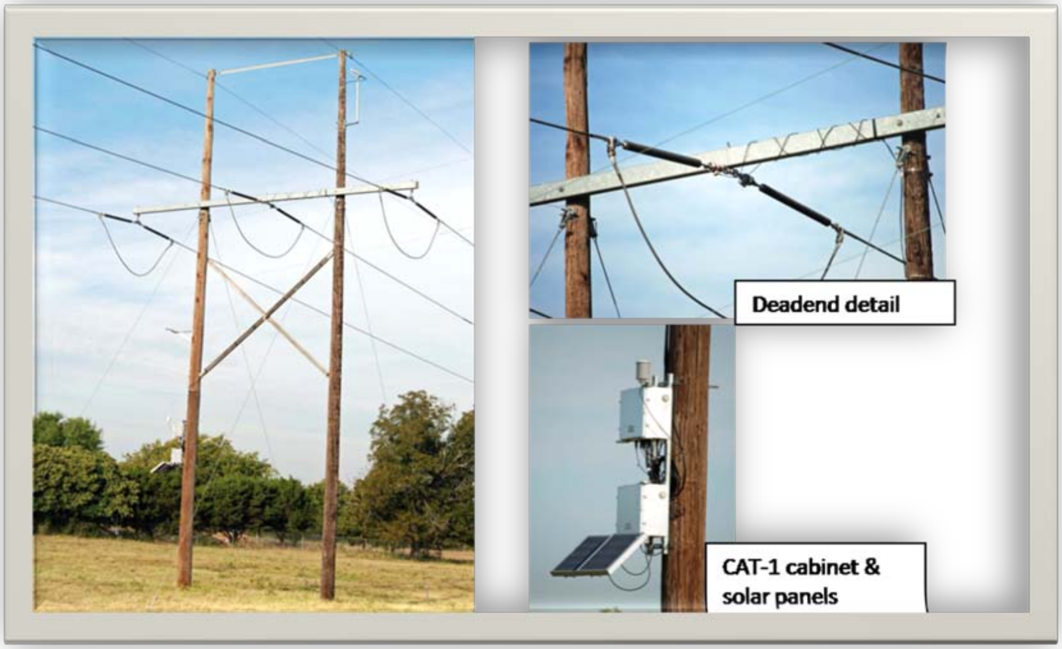


Figure 16 - 138 kV CAT-1 Installation

Along the eight different circuits, 19 loadcells were installed on the 345 kV lines and 26 loadcells installed on the 138 kV circuits.

As noted previously, various combinations of loadcells for a given line will be used to predict the dynamic line rating for the transmission lines. For every combination, the lowest available dynamic line rating is used to rate the line. By doing a statistical analysis of the data for various loadcell installations, a guide for selecting the optimum deployment of instrumentation will be derived.

2.2.3 Technology Validation

As part of the project, a validation and accuracy assessment of the DLR technology is being conducted. This task has two objectives: first – validate that the tension monitoring and DLR algorithm properly characterize the conductor by properly estimating the conductor temperature for a certain "reach" of the CAT-1 loadcell and second - validate the spatial capability of the CAT-1 device relative to its "reach" and the variability in span characterization within the monitored spans' length. For example, do small line angles, short versus long span in a section or the distance from a DLR device have a significant impact on the system's ability to characterize the conductor temperature under the current climatic conditions.

To facilitate this validation assessment, secondary monitoring systems are being installed on a variety of spans relative to the primary CAT-1 systems. The secondary monitors use two different technologies to monitor the conductor position in specific spans. The first system, known as the Sagometer™, is a camera mounted on a structure monitoring a target attached to the conductor a short distance into the span, refer to Figure 17. By correlating the target position with the full span behavior, the Sagometer is able to capture the conductor position at any given time. In Figure 17, the camera (seen in the inset) is mounted on the left pole below the conductor crossarm. The target is visible on the closest phase near the left side of the picture as a round dot hanging from the conductor. The Sagometer was developed by the Electric Power Research Institute and sponsoring utilities. It is marketed by EDM International.

Figure 17 - Sagometer Installation on 138 kV Wood H-frame

The second technology used for system validation is the Real-time Transmission Line Monitoring System (RTTLMS) by Promethean Devices, Inc. The RTTLMS is located on the ground under the transmission line. The sensors detect the magnetic field associated with the level of current flowing through the conductor. As Figure 18 illustrates, the multiple sensors detect the magnetic field strength and through their algorithm calculates the position of the conductors by triangulating the field strength associated with each phase.

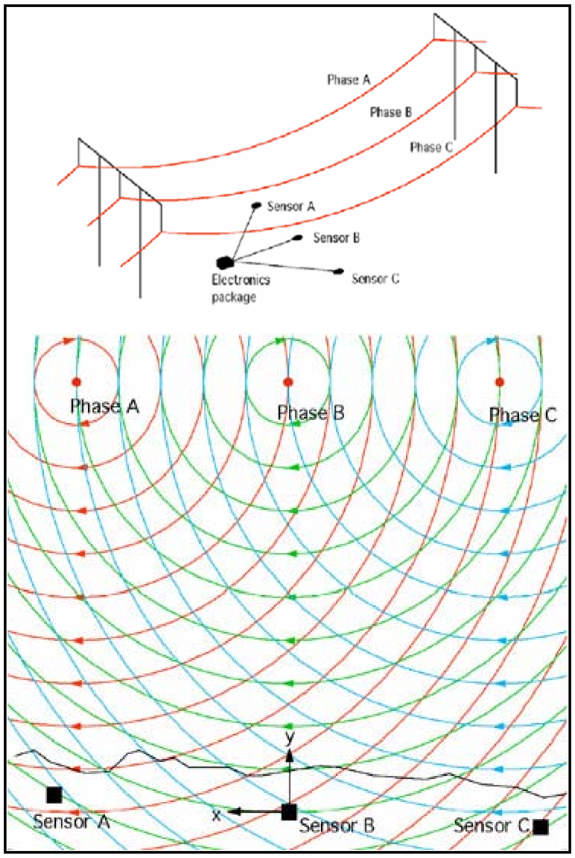


Figure 18 - RTTLMS Technology Overview

Figure 19 is a picture of the double circuit installation under a 345 kV line. The six phase sensors are located inside the faux-rock structures and connected via signal cables to the processor in the cabinet under the solar panels in the background. The white stakes are referenced points and not part of the instrumentation.

Both the Sagometer and RTTLMS systems are designed to provide streaming real-time data to a control room in similar fashion to the primary CAT-1 systems. The systems also have their respective algorithms to determine the dynamic rating of the line. For the SGDP project, they are not streaming data real-time to a control room, but providing a time-stamped data set of conductor position that can be correlated to synchronized timeframe data of the CAT-1 system. The sag position of the systems will be used to validate the accuracy and capability of the CAT-1 system to characterize a multi-span section of transmission line. Effectively, this validation process will calibrate and validate the overall DLR spatial accuracy to characterize transmission line operations.

Figure 19 - RTTLMS Double Circuit Installation Under 345 kV Line

2.3 Benefits Analyses

2.3.1 Capacity Above Static or AAR

The basic capacity study is to evaluate what percentage of the time; the DLR exceeds both the Static Rating and the ERCOT Ambient Adjusted Rating (AAR). For the more traditional operating environment where the static ratings are based on a fixed ambient temperature and wind speed, the availability of dynamic ratings will show a cumulative value above the static level similar to the plot shown in Figure 20 where the ambient temperature has a very low probability of exceeding the static rating ambient temperature base. For example, 104°F (40°C) is typically set as the ambient temperature for line ratings. If the utility is in the northern half of the country, the probability of having many days at or above this temperature is very low. Coupled with the simultaneous occurrence of a 2 mph wind, the probability of occurrence is likely less than 1-2%.

In the ERCOT region where Oncor operates, the probability of an ambient temperature greater than this static rating target is much higher and the “Risk” is greater. For example, the 2011 summer season experienced record numbers of days over 100 °F across the state. The Oncor service territory exceeded 100 °F 80 days this past summer.

The statistical capacity availability analysis will evaluate the magnitude and statistical availability of increased capacity for Oncor's service area and also take into consideration, the Ambient Adjusted rating.

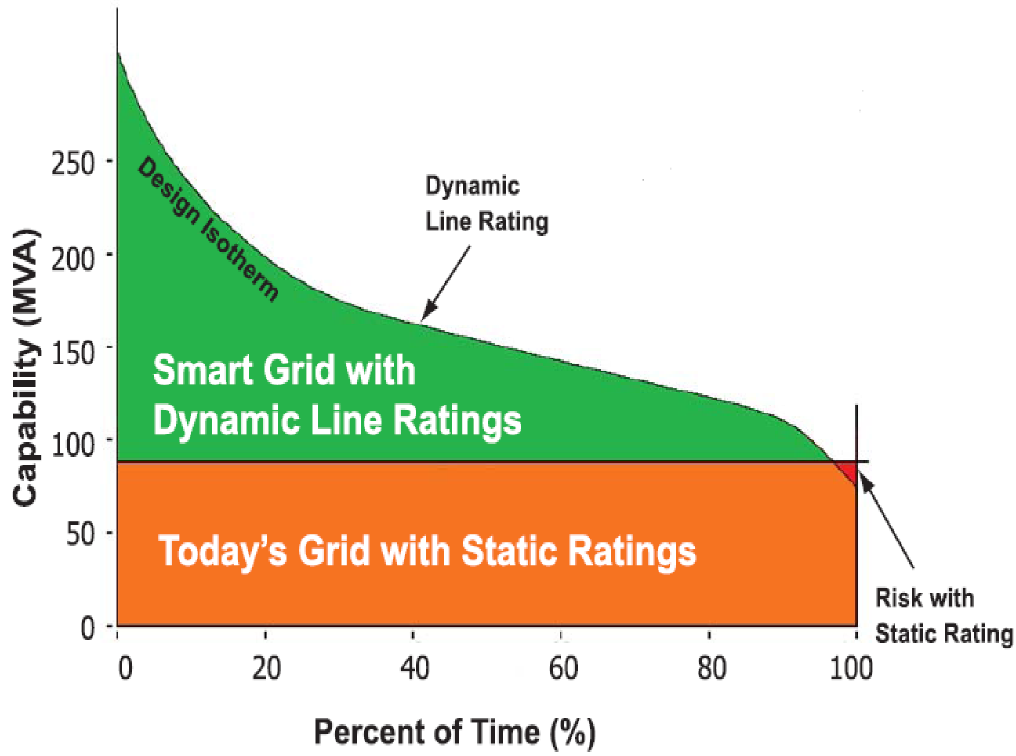


Figure 20 - DLR Availability vs. Static ratings

2.3.2 Persistence

One of the concerns about using dynamic ratings is how long a time frame an increased line capacity is available on a transmission line. This concept is referred to as Persistence. Will the increased capacity be available for the next 5 minutes, 15 minutes, 1 hour, 2 hours, etc? If the capacity is only available for short durations, its peak value may not be the value of interest, a lower level of capacity available for a longer period may be more valuable. Conversely if the persistence characteristic is of a longer duration, more of the DLR capacity may be depended upon. One of the studies being undertaken as part of the SGDP is such a Persistence study.

The rating persistence is important from an application perspective when the system operators need to depend on DLR's increased capacity and new generation must be dispatched to resolve a congestion problem,. Generation units have different start-up times between the dispatch request and when the energy is available on the grid. There is an integrated correlation between the persistence of dynamic ratings and its solution to various system energy demands and dispatch coordination.

2.3.3 Capacity Availability for Planning

The availability of increased capacity through the application of DLR can also be applied by Planning when considering deferring capital investments. If the capacity released by DLR has an appropriate level of availability when n-1 contingency demands and peak loading events occur, DLR can be used to provide the capacity required. This would enable Planning to push back physical construction and upgrades of lines thus deferring capital investments and optimizing operating costs for the utility. This project study will identify patterns in ratings that can be used to forecast future dynamic transmission capacity. Based on those patterns, a methodology will be defined that provides a practical and easily implemented forecast of future capacity. It is anticipated that the data will justify a methodology that raises the static limits presently employed in transmission system planning. However, that is not a foregone conclusion and other techniques remain open to exploration.

There is always some uncertainty in any forecasting technique. The degree of uncertainty that is acceptable and the impact of that uncertainty on planning and operations will be assessed.

Also to be assessed is whether a given methodology is universally applicable or if it needs to be tuned for a given set of conditions such as voltage class, size of conductor, length of line, and surrounding terrain.

2.3.4 Capacity Released by DLR

A major phase of the Project involves the reduction of the real-time data and the DLR forecasts to identify the opportunities for congestion relief during the monitoring periods following the derivation noted above. The Capacity Released Study will work through the real-time data and derivation model to develop a methodology to harvest events of congestion relief opportunity from the ERCOT data. Once these events are identified, their Constraint Relief will be identified by MW and duration. The 'Economic Trade Space Analysis Study' evaluating the economic impact will depend on developing a relationship with ERCOT to develop what the cost impact of the specific congestion relief is

If a transmission corridor is constrained such that the system would like to transfer more electric along a corridor than is possible, the Independent System Operator (ISO) will have to redispatch generation to meet load demand at a specific location. This may create an incremental cost increase for the energy due to the need to secure the additional energy from an incrementally more expensive generation source.

As Figure 21 illustrates, Oncor is the portion of the electric power delivery system within the red circle. As mandated by FERC and administered by ERCOT, Oncor Electric Delivery is strictly a transport and delivery service within the system, a Transmission Service provider (TSP). By regulation, Oncor is not allowed to know the incremental cost of generation that is impacted by congestion and congestion relief on its transmission lines. Nor is Oncor involved with the retail business of selling the power to a customer. Oncor is paid on a PUCT regulated basis for each Mw delivered between point A and point B, regardless of the owner of the power or buyer of the power. The economic benefits that the dynamic line rating protocol can create are reflected in the development of the cost of power at the delivery node.

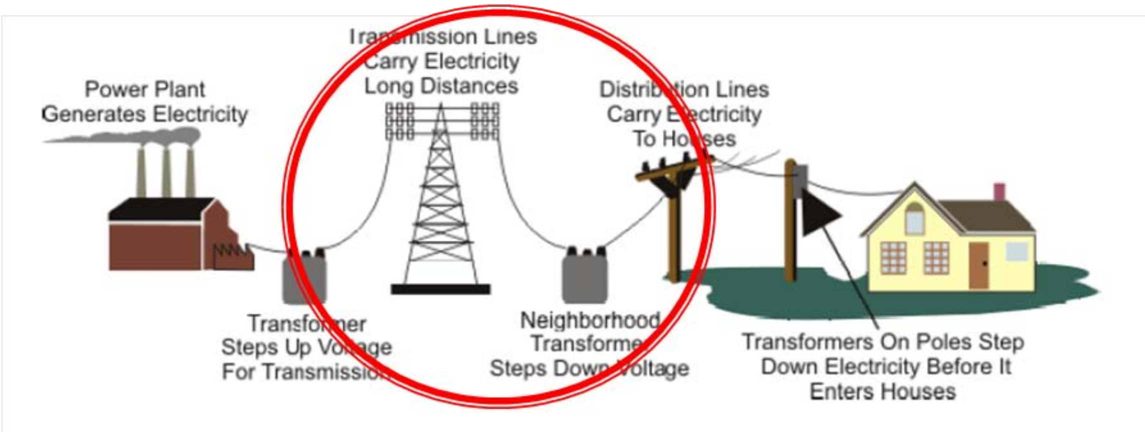


Figure 21 - Oncor Electric Delivery - The Power Delivery Portion of the Electric Business

Oncor has been working with ERCOT to identify a process to quantify the economic benefits of DLR in the operation of the ERCOT grid. As noted previously ERCOT has been operating under a Nodal basis since December 1, 2010. The ERCOT nodal market is basically divided into three time-oriented segments:

Day Ahead Market – the DAM is a planning stage where the generation entities identify and quote their proposed offering for the next day to sell energy on the market as energy or an ancillary service (power used to help maintain reliability and stability on the grid), A deliverable of the DAM is a list of potential congestion constraints based on the available transmission elements, forecast load and offered generation known as the DAM Shadow Prices The DAM Shadow Prices list the constrained transmission elements including line segments and transformers and their respective shadow price – effective congestion cost.

Real-time operations – during real time, ERCOT runs Security-Constrained Economic Dispatch (SCED) analysis that models the generation and transmission elements to match the load demand. SCED is run at a minimum of every 5 minutes and its result is generation dispatch commitment signals to every generator. The SCED Shadow Prices and Binding Transmission Constraints is a published list of active congestion constraints on the ERCOT grid again listing the transmission element and the effective cost of congestion across that element. When the SCED analysis is not able to solve a congestion issue, the system operators are alerted and they make specific decisions about redispatching generation to resolve an issue. Their decision is largely based on their experience with the grid and its characteristics. Their experience plays into knowing that selecting a specific transmission path and redispatch order may resolve several issues.

Settlement Period – every fifteen minutes, ERCOT creates a settlement entry that averages the cost of energy generated and delivered for 500 settlement point nodes. The load serving entities that bought the energy are invoiced based on these settlement points. The generation resources are paid based on their DAM offers and the amount of energy they provided.

Because the streaming DLR ratings to Oncor EMS and ERCOT are transparent, it is not possible to know when congestion events would be avoided by increased capacity from DLR. The added capacity is integrated into the SCED run and if that capacity resolved a transfer capacity need due to high loads or an n-1 contingency, the event or impact of the specific DLR differential rating would not be known. The only time that the DLR capacity would be recognized is if we could look at the SCED analysis with and without the DLR component. As noted in the discussion above, when the SCED run does not solve congestion issues, the operators will take additional measures to solve a specific congestion issue.

In order for the DLR SGDP project to quantify the impact of the increased ratings on operations, ERCOT and Oncor are developing a strategy to use the DAM analysis to provide an indication of the impact dynamic line ratings have on congestion relief. The DAM analysis models the day in 24 one-hour blocks and identifies where congestion events will arise due to load demands and generation resource availability/cost profile. By executing a DAM analysis based on the traditional ambient adjusted temperature ratings and a DAM analysis using actual DLR ratings in a post-processing analysis, a comparison of the impact of the DLR ratings can be achieved.

3. Project Results

3.1 Installation and Deployment

Deployment of the DLR equipment has been completed effective per the following stages:

3.1.1 Primary DLR remote sensing equipment – CAT-1s

Installation completed October 2010

Loadcell replacements – after several months of operation, degradation in the loadcell signal from the loadcell to the CAT-1 motherboard was identified on the 345 kV installations associated with the "floating-deadends". Upon examination, it was found that spark discharges from individual insulator caps to the signal wire were causing the wire covering to breakdown, moisture ingress and signal attenuation resulted. The loadcells and their signal wires were replaced and the insulator assemblies grounded in additional fashion to mitigate any discharges. – Completed July 2011

3.1.2 EMS System Upgrade

Programming completed in the Energy Management System to feed the DLR ratings through to the operating control rooms at Oncor and ERCOT - completed June 2011

3.1.3 Sag Validation systems

Sagometers - 5 installed in June 2011

Promethean RTTLMS System - 2 deployed in May and June 2011. Promethean systems are being moved to their second set of monitoring sites.

3.1.4 System Go-Live

The Go-Live of the system, i.e., actually streaming DLR ratings to the control room and SCED analysis, has been delayed due to the issue with the loadcell signal wires noted above in the deployment description. Following the replacement of the loadcells, a month long data acquisition period is required to complete calibration procedures. The calibration process has been completed and the data stream is working for the majority of the data. While the system is not actively being sent to the control room, all of the DLR ratings are being captured as well as the Static and Ambient Adjusted Ratings based on ambient temperature only. This allows full mathematical analysis of the data for all of the studies projected in the previous discussion.

An Operator's Guide for the Oncor control room is being drafted by the Operating Department to be used by the operations personnel. The EMS system has been programmed with appropriate logic to switch the ratings from DLR to the Ambient Adjusted rating if the DLR data becomes suspect or out of range. Alerts are transmitted to an operator's desk for corrective action to identify the problem. The system, as noted, reverts to traditional ratings without operator intervention.

Bringing DLR data into the control room and making operating decisions based on the data is a very sensitive issue. In fact, many utilities have deployed various DLR systems in the past only to have them stopped from bringing data into the control room or using it for operating decisions. The system operators are very concerned about introducing new operating issues especially one that can affect reliability and system availability. Accuracy and Reliability of the data are paramount to the willingness to accept the real-time data for operating decisions. That is why the Validation task outlined in our project is important to verifying the validity and accuracy of the data as well as it availability. If DLR projections are accurate about the latent capacity of the system that has always been there above the static rating, the operators are concerned about taking some of that buffer of operating capacity from the system and using it to operate with. Effectively they are reducing their operation margin of error and again the reliability and accuracy of the data is critical to their being comfortable using it.

For these reasons we are being cautious about when we go live with the system. We do not want to jeopardize the willingness of Oncor operations to work with the data real-time by putting a product before them before we are certain of the reliability and accuracy of that data stream. Again, the project's overall metrics are not jeopardized as we can perform all project studies with data as we go forward. We plan to go live as soon as the Operating Guideline is completed. The original project schedule anticipated a G0-Live date in January 2011. However, due to some of the installation and hardware issues experienced, the Go-Live date is anticipated to be late February 2012.

3.1.5 Cyber Security

Four key aspects of real-time data acquisition and processing are the focus of Cyber Security issues:

Confidentiality – prevention of unauthorized access to the information,

Integrity - prevention of the theft, unauthorized insertion or modification of information,

Availability – consistency of data stream availability to secure users and prevention of access by unauthorized entities, and

Accountability – clear documentation of any event, its time, source and purpose.

The AMI Risk Assessment document prepared by the Advanced Metering Infrastructure Security Task Force (AMI-SEC) was used as a starting point for the test plan. DLR is similar to other advanced metering of infrastructure in that we are monitoring the real-time status, metering the tension on the transmission line. The methodology outlined in the document was developed by the AMI-SEC working group within the OpenSG users group. This document has since been passed to the NIST Cyber Security Working Group to be integrated into documents that they are currently working on producing.

Appendix B.3 of the AMI-SEC document is an exhaustive list of threats that a potential AMI system could face. While the system, being tested here, is not an AMI system, the threats described are still applicable to the DLR system and can be utilized for test plan development. Using this threat list as a starting point, the list was first pruned down to only include threats that were applicable to the system and that were within the scope of testing.

Platform Communication Vulnerabilities

- Integrity Checking
- Authentication (Users, Data or Devices)
- Encryption
- Replay
- Protocol Usage
- Cross-Domain Injection
- Unnecessary Services

Physical Vulnerabilities

- Platform Hardware Vulnerabilities
- Chips/Exposed Ports
- Component Protection
- Tampering/Injection/Eavesdropping
- Platform Configuration Vulnerabilities
- Storage of Information
- Password Security/ Permission Levels
- Audit Logs
- Platform Software Vulnerabilities
- Packet Floods
- Handling of malformed data
- Code Protection

System level Vulnerabilities

- End to End Encryption
- Denial of Service (Handling, Recovery)
- Replay Attacks
- End Point Spoofing
- Audit Logs (Manipulation, Generation)
- Physical Tamper Detection
- Firmware Update (Verification, Process, Integrity Checking)

Next, for each threat that remained, a test case will be developed designed to determine if the system was vulnerable to that threat or not. Finally, an initial risk rating for each test case was assigned in order to help with test prioritization. The priority of testing is developed through an assignment of the severity of the vulnerability/threat and the likelihood of the threat occurring.

The flowchart of the process just reviewed is laid out in Figure 22.

Severity of impact addresses the degree of impact in two ways: the breadth of the impact, i.e., number of units impacted or the reach into the network and grid; and also relative to the economic/security/reliability/safety aspect of the impact, Table 3.

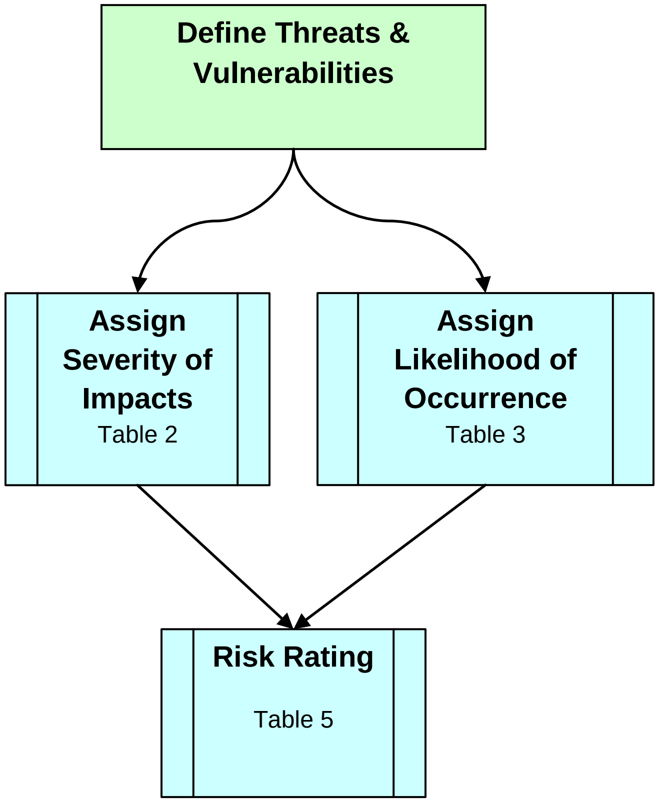


Figure 22 - Cyber Security Assessment Flowchart

Table 3 - Severity of Impact Ratings

Severity			
1	Negligible	Low	Effects limited to single unit / Minimal e/s/r/s impacts
2	Moderate	Medium	Effects limited to units in a single cell (NAN) / Moderate e/s/r/s impacts
3	Severe	High	Effects beyond a single cell (System/WAN) / Severe e/s/r/s impacts

The likelihood that a threat will occur or vulnerability be exposed is measured according to the descriptions in Table 4

Table 4 - Likelihood of Occurrence Rating

Likelihood / Threat			
A	Rare	Low	Exceptional circumstances only
B	Unlikely	Low	Not expected to occur
C	Possible	Medium	Could occur at some time
D	Likely	High	Will probably occur in most circumstances
E	Almost Certain	Critical	Expected in most circumstances

Once the vulnerabilities and threats have been reviewed relative to Severity and Likelihood of occurrence, their product probability defines a Risk Rating as shown in Table 5 and Table 6. The Risk Rating guides the Cyber Security assessment to perform its assessment on the most efficient path to address the issues of highest concern and impact.

Table 5 - Risk Rating

Risk Rating				
Likelihood		Severity		
		Negligible	Moderate	Severe
		1	2	3
E	Almost Certain	M	H	E
D	Likely	M	H	E
C	Possible	L	M	E
B	Unlikely	L	M	H
A	Rare	L	M	H

Table 6 - Risk Levels

E	Extreme risk
H	High risk
M	Moderate risk
L	Low risk

Figure 23 provides an illustration of the risk-prioritization rankings currently established in the review of the vulnerability and threats previously discussed. This type of information is beneficial in establishing which cyber security issues will be investigated further based on overall ranking. The High risk category represents approximately 35% of the issues. Approximately half of the concerns are rated Medium risk. The Cyber security analysis will drill down through these issues and identify a subset that will be completely assessed, while other issues will be shown of lesser risk and not assigned sufficient impact to fully investigate at this time.

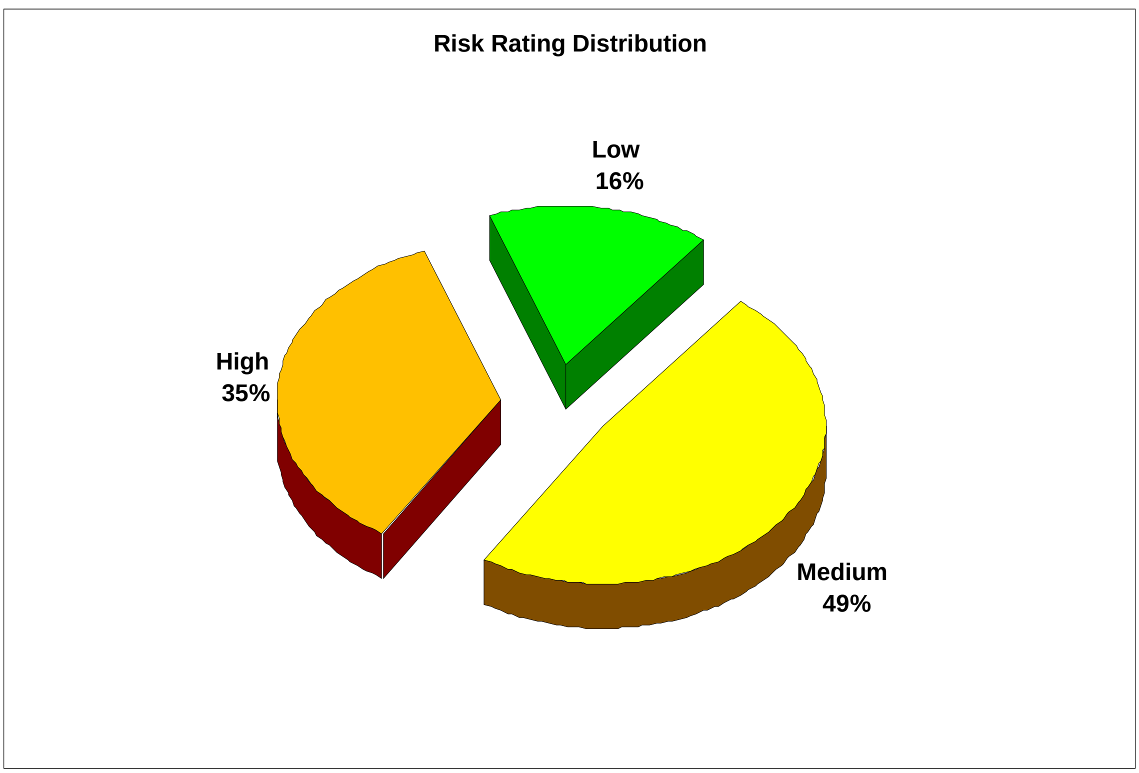


Figure 23 - Risk Rating Distribution Capacity Above Static or AAR

Data has been accumulated since the fall of 2010 showing a comparison of Static, Ambient Adjusted and Dynamic Line Ratings. This data will be used for a number of the economic and capacity studies previously laid out. The following two charts illustrate a snapshot of data for the same transmission line section for two days each from April and August 2011. In Figure 24, data for a 345 kV line in April is shown. As the data illustrates, the Ambient Adjusted Rating and Dynamic Line Rating are both greater than the Static Rating. The AAR is a minimum of 11% greater, while the Dynamic Rating is a minimum of 15% greater than the Static. The plots show the diurnal trend of day and night behavior as well as the influence of wind on the conductor, illustrated as the peaks for the dynamic rating.

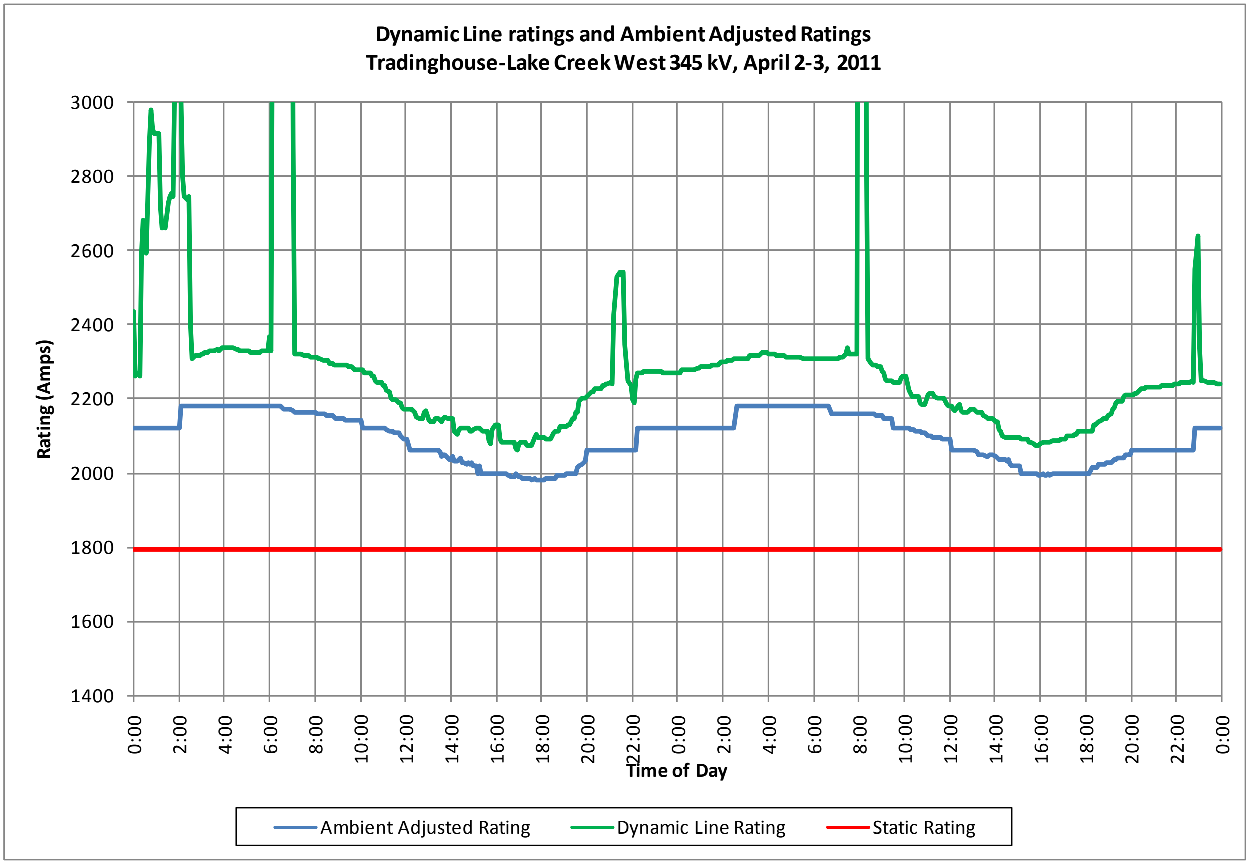


Figure 24 - Ratings Snapshot for April 2-3, 2011

In the snapshot view of data from August 2011 shown in Figure 25, the same line section is shown. There are several noticeable differences between the two snapshots. Since the line loading is higher in August and the overall conductor temperature profile is higher due to loading and ambient temperatures, the impact of wind is much more apparent as shown by the variability in the Dynamic Line Rating. Also note that there are periods each afternoon where the Ambient Adjusted Rating falls below the Static Rating, not by much but for considerable duration. Comparatively, the Dynamic Rating also has excursions below the Static and Ambient Adjusted Rating for a brief period one afternoon when the wind is not blowing across the conductor. Even through the variability is greater in August; the Dynamic ratings consistently provide greater capacity than the Static or Ambient Adjusted Ratings.

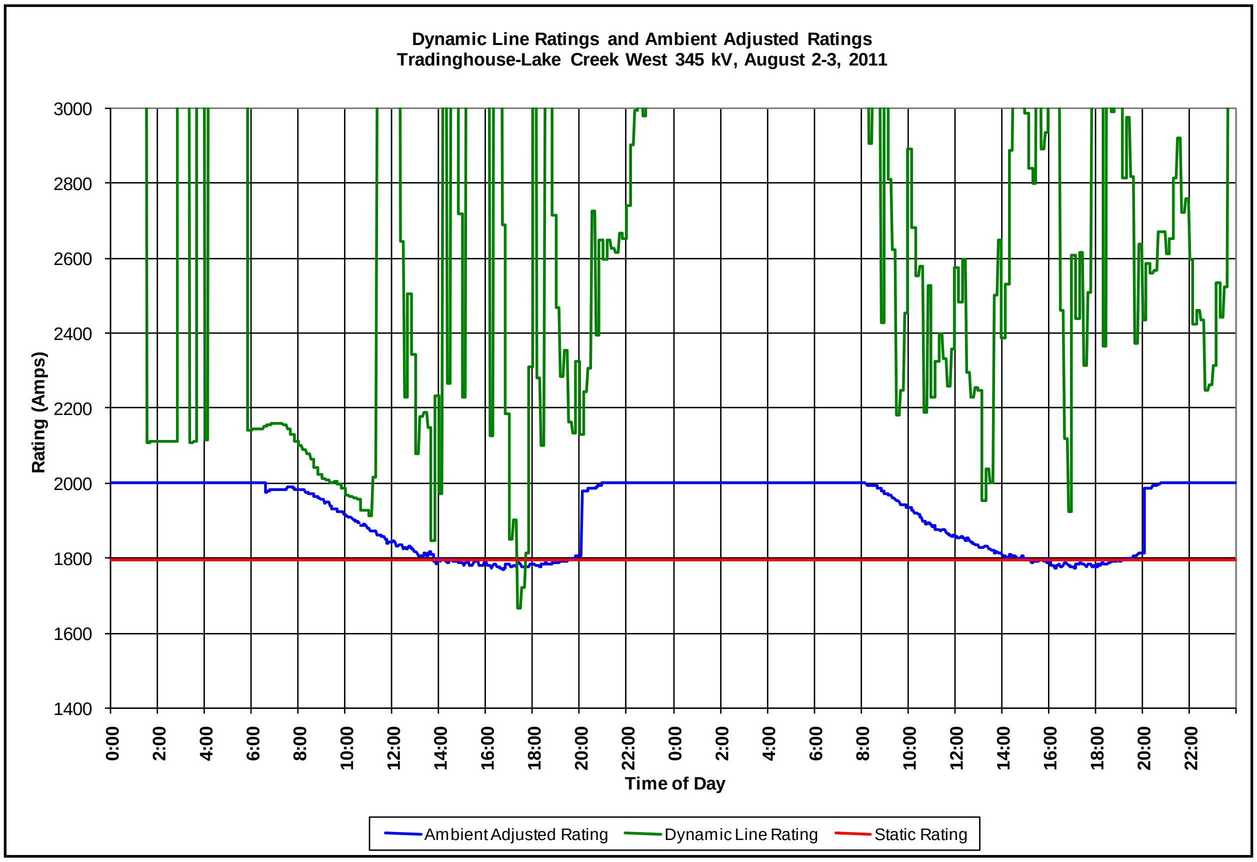


Figure 25 - Ratings Snapshot for August 2-3, 2011

This data will form the basis for the above captioned studies on capacity availability and persistence. With respect to persistence, the comparisons between the two figures are illustrative about the variation in the ratings that will be experienced on a seasonal basis. In Figure 24, the persistence of the rating can be seen to be relatively extensive. The peak excursions are shorter in term, but the first 15-25% capacity increase has longer persistence. In the summer season shown in Figure 25, persistence becomes a more critical aspect as the duration of increased capacity has greater variability. The Persistence study will be analyzing the data to establish guidelines on how the ratings can be applied with practical availability.

3.1.6 Technical Studies

- The results of the technical studies identified throughout Section 3 will be addressed in this section of the TPR. AT this time limited progress has been made on the studies as they are driven by analysis of accumulated data over the course of the project and the time period of reference to draw conclusions for the technical aspects is related to a minimum of a year’s worth of data. Study areas include:DLR Instrumentation Deployment Optimization
- DLR Instrumentation Accuracy and Reach Validation
- Persistence Analysis
- Capacity Available for Planning

- Alternatives to DLR to meet Increased Transmission Line Capacity
- Commercial Cost and Practicality for DLR Deployment.

3.1.7 Congestion Impact

From the data recorded to date, only one of the eight transmission lines monitored with DLR has experienced congestion. The Bosque – Elm Mott 138 kV line has experienced actual congestion on seven days in August and September (1 day late in August and 6 days in September – one string 4 days in a row). Table 7 summarizes the DAM and SCED views of the Congestion on the Bosque - Elm Mott 138 kV line. The day-ahead approximation of the next day's operation shows that the actual system operation experienced a greater level of congestion than the day-ahead model in both congestion cost and minutes of congestion.

Table 7 - Congestion on DLR Monitored Lines

	DAM Congestion	SCED Congestion
Congestion Impact	$ 259,000	$598,732
Congestion Minutes	166	209

Congestion costs are comprised of two distinct tiers of impact. Some of the costs are associated with the settlement LMP cost between the two nodes of the source of energy and the load sink delivery point. These costs may range from the nominal $30-45/MWH LMP to very high LMPs over $2,000/MHW. The second impact tier is active if a specific line actually requires relief via the operator sending dispatch signals to a generation resource. In these cases, ERCOT has a penalty rate established based on voltage level such that the KWH rate is $2800, $3500, $4500 and at times $5000. When these pricing structures are in play, the congestion impact escalates quickly.

As noted in the project description, the lines selected for monitoring and applying DLR during the Project were selected several years ago and it appears that overall system improvements and the enhanced granularity of the system view through the nodal market has diminished the amount of actual congestion along the eight transmission lines selected for monitoring. One point of note is that the Project lines were connected to two generating facilities that have been mothballed since the Project inception. When we look at the actual loads being carried by these transmission lines, they are seldom loaded above 25% of their capacity. The data shows they are seldom a constrained path even considering the n-1 contingency scenarios.

The fact that the lines are not actually being constrained or congested does not diminish the knowledge gained from the DLR project execution. The analysis and performance of the systems will continue to create validation data and future deployment criteria for protocols.

In order to more fully develop an economic impact and trade space analysis of DLR on system operations, we are looking across the Oncor system and analyzing the congestion trends. Table 8 provides a summary for congestion across the Oncor system for the period of mid June through mid-November. Impacts are shown for both the Day Ahead Market and the actual congestion incurred during real-time operation (SCED Congestion). The numbers indicate a heavier share of congestion being realized at the lower voltages than the 345 kV backbone transmission lines. The impact of n-1 scenarios on the operating protocols drives this pattern. When contingency scenarios are run for the loss of a 345 kV line, the power must be transferred on lower voltage lines that serve the same parallel path between generation source and load sink. If the 138 and 69 kV systems are not robust enough to carry the load, then congestion occurs and generation must be redispatched to serve the load over a different path. Granted in some cases, parallel 345 kV lines may serve this function, but the tendency is for the load to be carried by the closest transmission elements and they are typically lower voltage lines.

Table 8 - Oncor System-wide Congestion Impact

Voltage	DAM Congestion	SCED Congestion
69 kV	$20.9MM	$ 6.2MM
138 kV	$ 18.3MM	$ 23.1MM
345 kV	$ 4.7MM	$ 3.6MM
Total	$ 44.0MM	$ 32.9MM

The number of hours of congestion and economic impact of the congestion varies widely with each operating day. This is illustrated in the following two graphs that show the DAM Congestion and SCED Congestion for the same summer period sorted by date and voltage. In Figure 26 the variability is displayed by the number and size of the congestion costs distributed across the daily screen. The graph shows a higher concentration of congestion events early in the period, followed by a span of sporadic events of varying frequency and financial impact. Note that the 345 kV impacts are fewer and less significant than the 69 kV and 138 kV congestion.

Another variable in the congestion picture is the number of lines that experience congestion. During the period referenced in the previous description, over 104 lines experienced actual congestion impact during real-time operations as seen in Table 9. The 104 lines represent 10% of the circuits within Oncor.

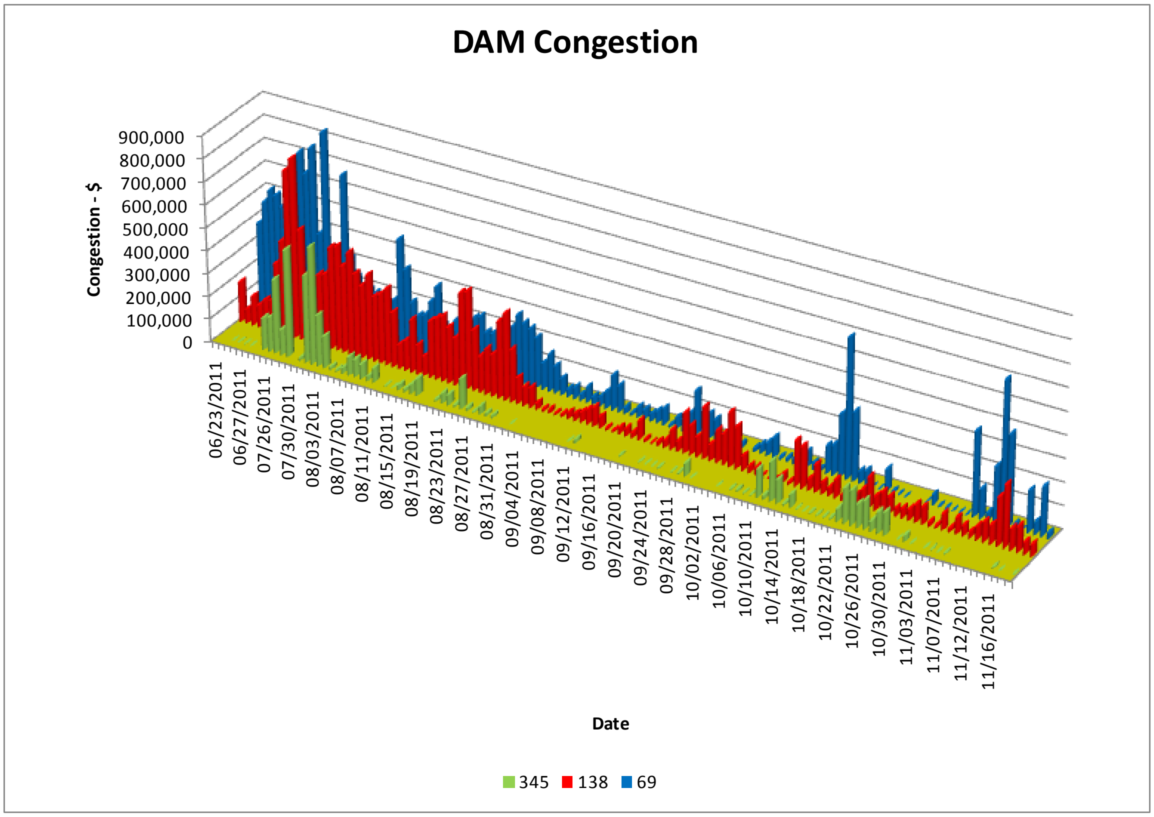


Figure 26 - DAM Congestion Variability Over the Summer of 2011

Table 9 - Number of Oncor Transmission Lines Impacted by Congestion

Voltage	DAM Congestion	SCED Congestion
69 kV	38	69
138 kV	171	28
345 kV	38	7
Total	247	104

Relative to congestion realized during real-time operations, the variability in frequency and number of events versus their respective financial impacts show that congestions' pattern is broad and somewhat difficult to pinpoint, refer to Figure 27. If the detail were shown for each line, each day or each voltage class, it would be apparent that while the financial impacts of congestion are great, their pattern is spread across many variables. The data has shown that the duration of the congestion events recorded so far cover less than 2-5% of the operating time of the line. The congestion may be for several 5-minute periods over a week with relatively high impact rates or some lines that have many more minutes of congestion but their hourly LMP may be relatively low and the cumulative impact of little financial consequence.

This dispersion of impacts is further detailed in Table 10 when you look at the monetary impact on a given line and the number of minutes the line experienced congestion. For example, the 69 kV Ackerly Lyntgear – Sparenberg line accumulated over half the dollar impact of all 69 kV lines and has the second highest number of minutes of congestion of all lines all voltages. Further, this line is in a very rural area of the system, very old construction with small conductor and only 2-3 miles long. This line is in the queue for reconstruction and upgrading to meet the load and congestion needs.

The majority of the impact as seen in all the tables and graphs so far is in the 138 kV lines. Of note, however in Table 10 for the 138 kV lines is that the high impact economic contributors typically have few minutes of congestion compared to many other lines in the data. These lines experience higher impact events and may be excellent candidates for DLR application. The lines do not need upgrading for base loading needs, but have a need for increased capacity on a semi-frequent basis.

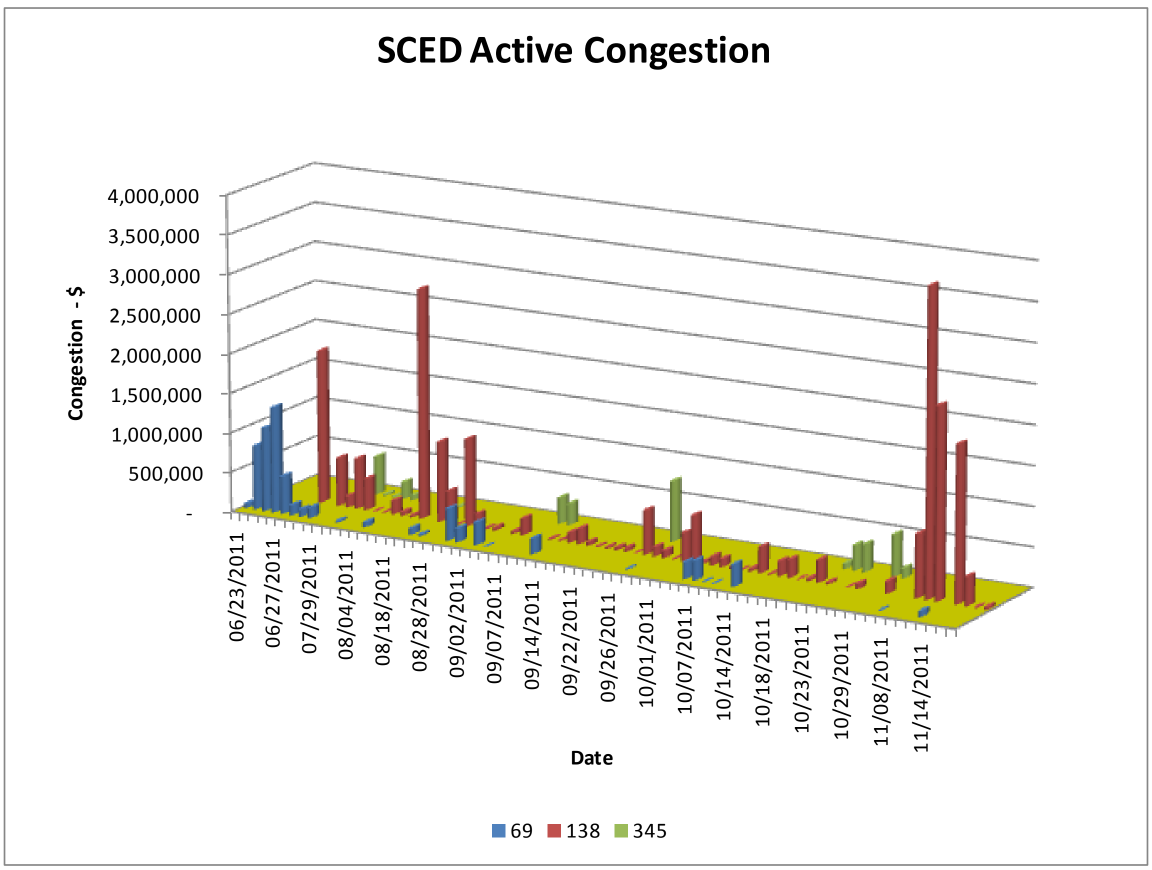


Figure 27 - SCED Congestion Variability Over the Summer of 2011

As mentioned earlier, the economic benefit of DLR will be estimated by taking a comparison of DAM performance with and without DLR on lines that experience congestion. Candidates for this comparison can be picked from the list in Table 10. A variety of impact combinations can be put in the DAM model and evaluated to see how DLR resolves the congestion impact. For example lines that have high financial impact for relatively few events versus lines that experience some congestion on a more frequent basis can be compared to further characterize the impact of DLR Congestion Relief.

The analysis of ERCOT and Oncor system congestion data has revealed a new aspect of the operation of the system previously unrevealed. The advantage of the granularity of the Nodal Market and the data available from ERCOT presents a great opportunity to evaluate and quantify the impact of congestion. The impact studies noted above will quantify the congestion relief that results from unresolved congestion events that need “hands-on” attention during operations. What is apparent from the studies so far is that the transparency of DLR streaming enhanced line ratings to an automated operating environment operating with a Security-Constrained Economic Dispatch engine has an immeasurable congestion relief benefit from the system automatically optimizing itself based on the Dynamic Line Ratings.

Table 10 - Congestion Lines - Dispersion Across Many Lines

Line and Voltage	Impact $	Minutes
69 kV	**6,209,073**	**9,445**
ACKERLY LYNTEGAR - SPARENBURG 69	3,773,606	6,215
SPARENBURG - LAMESA 69	1,522,111	2,666
ODESSA NORTH - NORTH COWDEN 69	625,102	349
ODESSA NORTH - ODESSA BASIN SWITCH 69	207,345	110
BOMARTON - SEYMOUR 69	75,460	50
SNYDER - AMOCO TAP 69	5,449	55
138 kV	**23,116,606**	**19,828**
CHINA GROVE SWITCH - BLUFF CREEK SWITCH 138	3,644,924	825
Apollo (BEPC) - RICHARDSON EAST 138	2,253,907	857
SAGINAW - AMERICAN MANUFACTURING TAP 138	2,144,149	219
MCDONALD ROAD - FORSAN TAP 138	2,121,263	895
CARROLLTON NORTHWEST - Lewisville South (TNMP) 138	1,936,754	140
FORSAN TAP - CRMWD #7 TAP 138	1,781,744	845
SEAGOVILLE - KLEBERG TAP 138	1,144,743	515
CARROLLTON NORTHWEST - LakePointe (TNMP) 138	1,119,827	318
GOLDEN SWITCH - BRAND 138	1,081,316	7,210
FISHER ROAD SWITCH - WICHITA FALLS 138	1,012,725	1,885
BROWNWOOD SWITCH - CAMP BOWIE (LCRA) 138	992,931	340
MESQUITE WEST - MESQUITE WESTERN ELECTRIC 138	891,458	1,410
FOREST GROVE SWITCH - MABANK TAP 138	854,519	1,460
ALLEN SWITCH - PLANO CUSTER ROAD 138	634,768	55
Bosque Switch (BEPC) - ROGERS HILL (BEPC) 138	590,065	1,035
ODESSA - ODESSA NORTH 138	378,022	303
SANDOW SES - SANDOW SWITCH 138	152,534	585
FISHER ROAD SWITCH - WIND CREEK 138	149,731	265
FLAT CREEK SWITCH - LEON SWITCH 138	68,580	93
MOSS SWITCH - AMOCO NORTH COWDEN TAP (TNMP) 138	40,458	25
MIDLAND EAST - WINDWOOD 138	36,443	30
BIG SPRING SWITCH - COSDEN 138	19,636	180
BARTON SWITCH - ORAN 138	18,471	135
CEDAR HILL SWITCH - FISH CREEK SWITCH 138	15,942	55
LEON SWITCH - FLAT CREEK SWITCH 138	12,443	15
ROGERS HILL (BEPC) - ELM MOTT 138	8,307	10
DAVIS STREET TAP - EULESS TRINITY BOULEVARD 138	7,935	113
CEDAR HILL SWITCH - MAYFIELD TAP NORTH 138	3,009	10
345 kV	**3,581,162**	**4,820**
JEWETT - RATTLESNAKE ROAD SWITCH 345	2,031,388	1,855
Limestone SES (HL&P) - JEWETT 345	655,301	1,785
TRINIDAD SES - WATERMILL 345	399,931	170
BELL COUNTY EAST SWITCH - TEMPLE SWITCH 345	247,592	797
RICHLAND CHAMBERS SWITCH - TRINIDAD SES 345	168,195	128
JEWETT - BIG BROWN SES 345	73,479	50
BIG BROWN SES - JEWETT 345	5,277	35
Grand Total	**32,906,840**	**34,093**

3.1.8 Stakeholder Feedback

Oncor has had several interaction opportunities with Stakeholders within ERCOT and peer transmission service providers to discuss the project objectives. In the spring of 2011, the Texas Reliability Entity (TRE) held its annual programs for recertification of all regional operators of transmission and generation assets in the ERCOT system. Oncor's representative on the board of the TRE training committee proposed that the Project present an overview of the DLR SGDP to all of the operators. A one-hour presentation on the concept of line ratings, dynamic ratings and their importance to system operation was prepared including a discussion of the DLR project. The training session was provided to over 800 attendees over a seven week period. The reception was mixed in interest; perking up the ears of attendees associated with generation (DLR could increase the capacity of outlet lines from power plants at a very low cost) to moderate interest by grid operators who would see the streaming line ratings and make decisions upon them. Their interest was directed towards the reliability, dependability and accuracy of the data.

A presentation of similar context was also made to over 400 transmission line engineers at the annual University of Texas at Arlington Transmission and Substation Design and Operations Symposium.

Meetings with ERCOT staff have also been held on several occasions. The first meeting made a brief presentation of the scope of the SGDP DLR program and its objectives. The purpose of the meeting was to solicit from ERCOT their cooperation in helping the project identify congestion events and develop a process to quantify the economic impacts of DLR on the Oncor and ERCOT system. ERCOT made a commitment to Oncor and the Project to work with us to achieve these objectives and several ensuing technical discussions have provided direction and data support to meet project objectives.

Internally, the Planning Department has expressed interest in the way the ERCOT SCED and DAM data have been analyzed to identify where and when congestion has occurred on the system. The ERCOT Nodal data has much greater granularity, accuracy, detail and timeliness compared to previous data. It represents a new tool for Planning to evaluate the system improvement needs of the transmission grid.

Stakeholder feedback has been extremely supportive and interested in the Project's progress and technical deliverables to date.

4. Conclusions as of December 2011

The DLR Project has had initiating strains that were unexpected but made tremendous growth in understanding how dynamic line ratings can and will impact the operations, planning and financial aspects of the delivery of electric power via transmission lines. The savings potential realized from congestion relief and capital investment deferment and optimization will be multiples of the investment in DLR.

4.1 Projections of Demonstrations and Commercial-scale System Performance

The Project has not yet reached the point in its schedule that calls for quantifying specific economic benefits from the application of DLR. However, the analysis of data and development of economic assessment methodology for the project have demonstrated several potential avenues for defining substantial benefits as discussed in Section 3.1.7.

A paradigm change in the aspect that DLR is used has been recognized. DLR was traditionally targeted for transmission lines that are operating close to their electrical capacity limit. DLR would define the margin of capacity available when all ambient conditions are incorporated in the conductor rating model and allow operation of the line at those levels without fear of violating any clearance and safety constraints. The paradigm shift is that the majority of the lines that experience congestion are physically not close to operating at maximum levels…they have the potential of operating above maximum level if an n-1 contingency occurs and the line is called upon to operate at a higher level. The n-1 constraint, more specifically ERCOT's operating criteria, governs the Independent System Operator's protocol.

The variability in system characteristics and daily operating status from ambient weather conditions, load forecast and the status and market drivers of the generation resources all make the transmission grid within an ISO's control very fluid. The result is that congestion is just as variable in location, timeframe and magnitude. The data has shown that certain lines are chronic with congestion. Some of these lines are high economic congestion forces. Some chronic lines have minimal economic impact. Other lines or equipment are acute congestion players. Some unique system driver such as the loss of a large generation unit or multiple units will cause large congestion impacts.

The congestion data indicates the opportunity to relieve millions of dollars of impact with small amounts of increased capacity. The Project will provide guidance and methodologies to locate and deploy a DLR system to mitigate the congestion across a single utility or across an ISO region.

4.2 Lessons-Learned and Best Practices

Several lessons have been learned from the Project to date.

- First of all system characteristics are not static. The lines originally selected for the Project, identified for their significant congestion, have demonstrated minimal congestion in the first year of the Project. System changes altered the flow of energy across the grid. New lines, line upgrades, load demand differences, and generation availability have all made changes to the grid operation in the Project area. The point to note is: DLR can be a responsive tool to resolve a situation that has a time reference of unknown length but in all probability is shorter rather than longer term (past 3-4 years).

- The CAT-1 system requires an accurate realtime data feed of the line current in each CAT-1 location. Without that datum, the algorithm cannot be accurately referenced to the line's state. This situation arose on several of the 138 kV lines where some of the substation terminals were owned by neighboring utilities and not Oncor. The access to the realtime data is not timely enough to satisfy the algorithms needs. In another case, there are several un-metered taps off of the transmission line which prevents access to the accurate loadflow in adjacent line sections. The take-away is that an incorporated line current sensing device or additional line metering is needed to completely utilize the DLR capability.
- The operation of equipment in a high voltage environment requires extraordinary precautions for grounding. The tangent 345 kV CAT-1 installations were placed on "floating deadends" as discussed in Section 2.2.2. Bonding leads to maintain near ground potential at the end of the vertical (suspension) insulator string were wrapped around the insulator and bonded to the tower arm. However, since the insulator string was comprised of ball and socket insulators, a number of the individual insulators' capacitive charge built up in the insulator cap until it sparked to the closest ground. Sometimes that was the bonding lead, but at times it was the signal wire from the loadcell causing signal degradation. The issue was resolved with additional bonding of each insulator and a conduit shield for the signal wire. This issue caused an 8 month delay in calibrating and setting up the CAT-1 DLR algorithm.
- The timeliness of deployment and bringing a DLR system on line is important. In response to the previous note, the identification of a congestion issue and its life span make response time of a DLR deployment critical. Deployment, calibration and validation of the DLR rating need to be achieved in a timely manner so that data can go online more quickly.
- Control room acceptance of DLR data and the operators' decision to apply the data remains a critical issue. The system operators' responsibility is reliability. Reducing congestion is not high on their critical list. Applying DLR in their viewpoint takes some of their working buffer away from them and uses it in actual operation. It is imperative that when data goes to the control room it is reliable and accurate. It is critical that no false-steps of Go-Live and then pulling it back are taken. Confidence erosion is damaging if not fatal to DLR deployment success.
- The fact is that a majority of the congestion issues or events are n-1 driven. This aspect needs to be incorporated into the deployment philosophy to mitigate some of the loss of buffer anxiety discussed in the previous note.
- From a best practices standpoint, the availability of market data and operations data from the ERCOT Nodal Market makes congestion more identifiable by time, location and specifics. All of these tags make the selection of optimal DLR application more efficient.

5. Contacts

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