Dynamic Line Rating in the world – Overview

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1. Introduction

The energy market is created to ensure that consumers receive the lowest possible price for electricity. Load growth and generation facility development particularly new distributed/ renewable energy resources development are much faster than transmission development. As a consequence, the transmission lines become constrained. Due to these constraints the energy market cannot assure the lowest possible electricity price for all consumers.

The transmission projects rely on several options to remediate transmission constraints. The most expensive and time consuming option is to acquire new transmission corridors and building new lines. Less expensive is revitalizing existing facilities by installing new conductors and transformer technologies or upgrading the critical spans and equipment. The least expensive are options that use the existing facilities up to their real physical capacity rather than assumed conservative calculation that are common practice in transmission design.

If the real conditions are continuously measured more appropriate rating can be calculated. This is called Dynamic Line Rating (DLR). While using DLR, the utilities around the world are reporting multiple operational and financial benefits. The lessons learned from these reports are that the consequences of not using DLR and other Real Time applications for the assessment of Available Transmission Capacity might be the loss of millions of dollars in one jurisdiction[1]. This might be due to several reasons such as unused transmission capacity, potentially unforeseen impact of contingencies, un-necessary curtailment during forced outages, or not detecting N-1 bottleneck conditions during wind ramps.

It is recognized that complex obstacles exist for DLR deployments and they must be holistically analyzed in order to achieve success. In this article, variety of referenced sources indicate the value of DLR to improving grid operations, relieving constraints and the financial return.

2. DLRs are mature technologies

DLR technologies have been in service in world utilities since 1977. In 2013_Q3, there were more than 2000 DLR installations in over 50 jurisdictions. Over one hundred utilities have used DLR. Over 32 vendors offer their own DLR products to the market based on different principles, different complexity levels, different prices, etc. The products use a variety of physical properties and sensors for both the transmission line and the environment to help define a real-time limit which is more appropriate than the commonly used Static Line Rating (SLR).

[1] Electrical system is under provincial, state, or individual countries jurisdiction.

2.1. DLR can solve Safety Problems related to SLR Accuracy

Traditionally, industry relies on the worst case weather conditions for calculating SLR. This simplifies equipment specification while providing significant safety margin. But, it would be wrong to assume the real rating is always greater than the SLR.

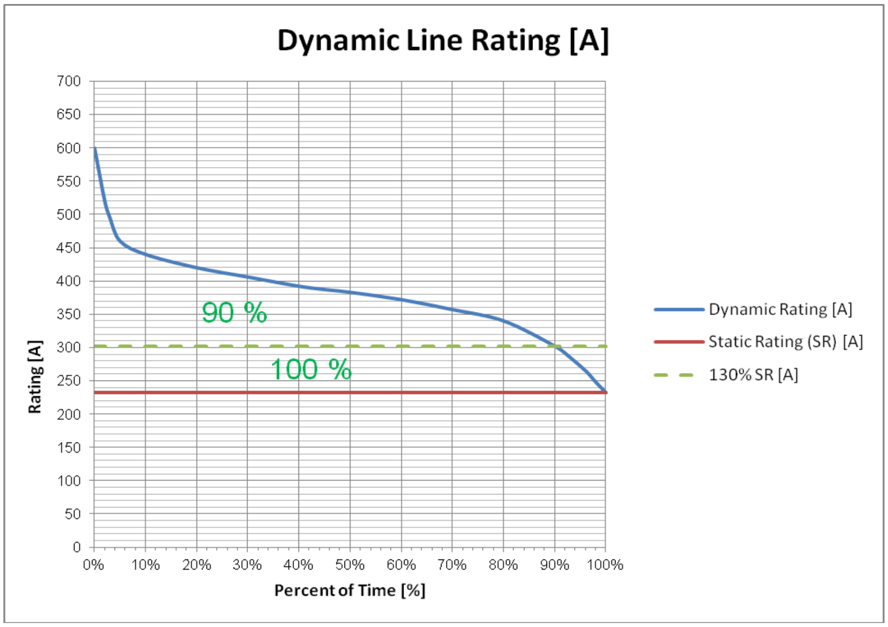

Fig.1. DLR – Common Expectations

The power industry has accumulated enough evidence that many PL could safely run up to 130% of static rated capacity for 90% of the year (Fig. 1). When this unused capacity is activated through DLR, more customers can connect to the existing grids without requiring construction of new PL and related facilities.

The assumption underlying SLR is that conductor temperature and line sag are deterministically correlated. However, real-life finding is that this assumption is correct only in a controlled lab environment. In the field, these two parameters (wire temperature and sag) are stochastically related - not deterministically. To address this as the major safety concern, several alerts have been released by IEEE[i], NERC[ii], CIGRE[iii], etc. identifying a variety of possible measuring errors that interfere with validity of both SLR and DLR results.

Although, the technical issues affecting the validity of SLR are identical for DLR, they were unknown until DLR project validation testing revealed them. A recent line-to-ground fault incident, root-caused by fundamentally wrong SLR calculation, suggests that industry ratings are sometimes[2] generous not conservative. This calculation error translates directly into reduced public safety. Therefore, DLR technologies include measurements for both parameters (wire temperature and sag) to identify the correct rating under real conditions.

[2] 5% to 10% of time the weather conditions are un-favorable for wire-cooling (for example zero wind speed @ high ambient temperature)

2.2. Common trends in DLR implementation

Experts' written guides exist to help utilities in making informed decisions about options for DLR. These guides identify the potential benefit in a given situation but it is still up to each utility to study their own system and determine where those situations exist.

There are more than one thousand reports about various DLR projects. Positive messages from these reports are the reasons that IEEE[iv], EPRI[v], FERC[vi], NERC[vii], EU Commission[viii], US DoE[ix] etc. have recommended DLR technologies to solve transmission constraints.

Power System design tools (e.g.: GE/PSLF, PowerWord, V&R Energy POM suite, DSA Tools, PSS/E, Rate Kit, PSCAD, PLS-CADD etc.) are ultimately based on SLR. Traditionally they use bus-brunch planning model to perform a system assessment. There is a trend to use snapshots from State Estimator and full topology model in real-time that would allow a dynamic assessment of system limits. BPA and WECC have already developed these capabilities.

2.3. DLR benefits

DLR projects usually provide several of the following benefits:

- ✓ Congestion relief of PL
- ✓ Improved grid reliability
- ✓ Reduction of transmission capacity curtailment during contingencies
- ✓ Optimized asset utilization and additional income from existing assets
- ✓ Better prices for consumers
- ✓ Better access to the market for wind generators
- ✓ System operator's informed decisions based on true PL capacity in real time
- ✓ Faster integration of Distributed Energy Resources (DER)
- ✓ Enhanced Wide Area Situational Awareness (WASA)
- ✓ Improved cost effectiveness of PL
- ✓ Avoidance of the cost of PL construction just to meet load requirements for a short portion of the year
- ✓ Reduction of the overall cost of PL upgrades by spreading them out over several years.

3. World Examples of DLR installations

The benefits from DLR technologies are illustrated by following examples. After their initial pilot DLR projects' satisfactory results, many utilities have deployed DLR as permanent solutions.

-Elia (Belgium utility) and RTE (France utility) have 15+ year history of the joint DLR system development with multiple benefits reported in public and private documents. The recent development of the Ampacimon system and it's validation through surveyor measurements of sag demonstrated up to 200% of rated capacity was available in some circumstances[x]. Starting in 2013 Q2, ALSTOM promotes Ampacimon's DLR application together with their EMS software that helps to unlock additional capacity while at the same time allowing operators to have better visibility of their network to increase load, prevent overloading and detect line issues, such as icing.

-Red Eléctrica de España (Spain), MRSK Holding (Russia), Idaho Power (USA) have each used DLR for several years and are continuing DLR deployment.

-TransGrid, Sydney, NSW, Australia, has implemented a DLR system on several 330kV and 132kV transmission lines in response to thermal limitations. This system produces a more intelligent grid by utilizing weather stations that employ mobile telemetry, where these are installed directly on the steel lattice structures.

- Oncor (ISO Texas) / ERCOT (TFO Texas) have an extensive program for 20+ years to operationally manage congestion[xi]. Their Dynamic Rating system is credited with most of the congestion cost reduction from $405 million in 2003 to $42million for the first 11 months of 2007.[xii] This is an on-going program with $7.5M spent in 2010-2012[xiii] focused on increasing the carrying capacity of PL and removing transmission system monitoring obstacles that prevent utilities from using DLR technology. Clearly, the value of DLR to the consumer has been proven to PUCT and the Texas ISO if they are spending money to help utilities to apply it.

- BPA reported[xiv] significant benefits from DLR for transmission capabilities under contingency situation on the West of Cascade North transmission path. For example on May 20, 2010, after applying dynamic calculations, the upper System Operation Limit was enhanced from 6425 MW (static rating) to 7537 MW (dynamic rating), or 1112 MW or 17% increase. That dynamic change reduced energy curtailment by 35%. PGE (Portland General Electric) and PSE (Puget Sound Energy) has estimated that they lost over $1M in two days prior to BPA application of DLR since they have not been able to wheel cheaper generation from Mid-Columbia plants into their load centers. Also BPA lost revenue due to the curtailment of firm transmission in 3 days.

- UK Gov (Office of Gas & Electricity Market - OFGEM) reported[xv] on April 04, 2013, that DLR is used on all major circuits in England and Wales to help reduce the costs of congestion that is estimated [xvi] at a range of $345M - $1,980M in 2020.

- NYISO/ NYPA conducted a 15+ year DLR program that has resulted in DLR deployment into Real Time Market[xvii]. The RTM includes pre-, and post- contingency analysis to improve congestion relief, optimize asset utilization, lower prices to consumer etc. The estimated congestion costs[xviii] in NY State are $1,260M annually.

-Central Networks at Skegness, North East of England sees capacity increases of up to 30% on lines connecting windfarms when it is most required.

-Manitoba Hydro used DLR technologies to evaluate their static ratings for DC bi-poles 1 & 2 and deferred capital investment in construction of bi-pole 3 for up to a decade as a result of the capacity identified. This delay directly resulted in lower consumer bills because the cost was spread across more consumers, when bi-pole 3 did go ahead. The 2002 results showed that Dynamic Rating is 30% higher than Static Rating 90% of the time or always higher 100% of the time.

-EirGrid, Ireland's transmission system operator deploys DLR special protection schemes combined with other Smart Grid solutions to manage a high proportion (up to 75%) of the wind energy on its system. Operation of the system is being improved through state-of-the-art modeling, weather forecasting and decision-support tools that provide real-time system disturbance & stability analysis, wind farm dispatch capability, improved wind generation forecasting, and contingency management.

-Central Networks at Skegness, North East of England installed DLR system to enable more wind generation to be connected to the grid. The project shows the potential capability to uprate the transmission line with real-time ambient monitoring, and even more than 30% of averaging uprated power with conservative assumptions.

- Carnegie Mellon University, PA, USA created transmission system model [xix] that calculates transmission constraints based on phase angles gathered from WASA. This simplified algorithm does not need the entire grid topology, but it modifies grid topology only locally near the transmission line that is evaluated from the transmission capacity perspective. The simplified approach helps system operators gain knowledge about real-time status of transmission capability much faster and more accurately.

These examples demonstrate that DLR is being applied effectively to manage transmission constraints around the world. When DLR projects conducted properly, many of the installations have proven the validity of specific technologies and the financial value of using DLR. Based on experiences throughout the world, first DLR projects always require government money.

The financial benefits from DLR to the transmission grid are not measured by the cost of construction projects completed but rather construction costs avoided and financial savings from deferring construction. The financial value to consumers is best measured by evaluating the generation dispatch differences between a static rated grid and a dynamically rated grid. The generation studies in particular are more easily done after the fact. (i.e. answering the question "What would the generation dispatch and market price have been without the DLR system?")

4. ISO & TFO approach to DLR deployment

4.1. DLR implementation issues

Trends in new generation development and requests for new load interconnection are happening faster than transmission system development. It means the transmission line capabilities do not fully match the new generation capabilities or the new load. As remedies for such systematic discrepancy, DLR solutions are becoming widespread around the world.

Part of the challenge with DLR implementation is that project objectives, goals, deliverables are not always clear. This has a big negative impact on the project's outcome. Utilities usually blame DLR providers for implementation project failures.

DLR technologies are near maturity, but not perfect yet. DLR vendors vary significantly from one to another in complexity of their solution, its reliability, accuracy, price, etc. In the past, many utilities may have assumed that a DLR vendor will provide a 'turn-key' solution that will have only minimal impact on their existing infrastructure. However, utilities soon learned that even the most basic application of DLR deployment requires changes to the control system so that the new calculated limits can be recorded in the historian, applied in the alarm system, state estimator, contingency analysis sub-systems etc. Modern EMS/SCADA systems make this integration relatively simple to achieve from Basic Connectivity and Network Interoperability prospective but the effect on TFO's and ISO's Business Objective(s), Business Procedure(s) and Business Context is not clearly defined at the beginning of the DLR project.

Another reason for slow DLR implementation is that regulatory environment does not stimulate TFO to invest in asset utilisation efficiency. DLR is a form of asset utilisation efficiency.

4.2. Future approach to DLR deployment

When a transmission constraint occurs, there are economic consequences for Energy Market participants, particularly for generators and loads. By definition, the transmission constraint is an event that occurs when available, least-cost energy cannot be delivered to all loads for a period of time because transmission facilities are not adequate to deliver that energy to some loads. Constraint obliges ISO to dispatch higher-cost generation to meet the load demand. When the required, more expensive generator runs due to the constraint, the ISO has to pay compensation no greater than the amount that would result in the recovery of fixed, operating and maintenance costs, including a reasonable rate of return. This cost is then passed on to consumers (loads). Therefore, the owner of the constrained transmission line is not directly affected by this circumstance, nor is stimulated to rush to remove the constraint.

In many jurisdictions, ISO is essential to DLR deployment. It is important to have a jurisdiction-wide strategy for DLR deployment, maybe as a part of transmission constraints management or as a part of Reliability Coordination group. The most often, ISO is responsible for forecasting transmission needs, prepare the transmission development plan and must apply for PUC[3] approval before directing a TFO to design the required transmission capacity. While waiting for new capacity, the ISO might choose one of the several different remediation means: operational management, DLR installation, PL upgrading (enforcing) or new PL construction.

Low-level transmission constraints (e.g. congestion for less than a few hours per year) are very common, but it would not be economical or practical to eliminate all such constraints. The majority of them are best handled through operational actions and maintenance scheduling. An effective DLR deployment strategy defers transmission upgrades due to small constraints.

DLR implementation strategy should include:

- Always adding an option for DLR or other new technology to the alternatives studied. The world leading utilities/ ISOs have conducted DLR demonstration projects that can be used as standard cases for alternatives studied.

- Adding these types of new technological options to the expectations when the ISO directs them to develop a new proposal for transmission improvement.

- For TFO one of the most important aspects of a 'pilot' DLR project is to allow the project to report a failure of the equipment, remove it from service or evaluate several different products. The unacceptable implication of Transmission Regulation is if that replacement of a failed pilot is paid out of the TFOs' maintenance budget.

Also, smart grid interoperability should be considered to ensure long-term development requirements for DLR integration with other applications within TFO/ ISO infrastructure. Many international and national documents state that systems with high interoperability have lower equipment costs and lower information transactions costs, higher productivity through automation, more conversion of data and information into insight, higher competition between equipment suppliers, and more innovation of both technology and applications.

Integration of large number of renewable energy sources often drives new transmission construction or DLR deployment.

5. Conclusions

To be safe, transmission systems designers assume the lowest capacity on any line. But through DLR, utilities can look at what the real capacity is at any given moment and adjust accordingly. The power system topology as well as environment (ambient temperature, wind speed and direction, etc.) surrounding transmission lines make the real rating higher than static most of the time. Many experts and politicians are recommending DLR technologies as less expensive alternative to expensive new power line construction.

There are many DLR solutions available on the market but for those solutions there is no clear guidance on when they will be cost effective. Many of DLR solutions are mature enough. Bigger challenge for DLR deployment is in power utility’s & independent system operator’s ability to integrate them into existing operation, maintenance, protection and planning solutions. In those jurisdictions where holistic approach to DLR deployment has taken place have better results than those jurisdictions with sporadic pilot DLR projects. If DLR deployment is considered as a part of Smart Grid road map, the cost sharing with other applications provide better chance for financial success.

[3] PUC – Public Utility Commission

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