This document describes the basic steps taken for implementation of dynamic line rating (DLR) and power flow controller (PFC) grid enhancing technologies (GETs) for implementation into a utility system. Either system could be installed separately or together. This gives the utility an idea of the data gathering that needs to be done as they discuss the installation with a vendor, such that needed information can ideally be collected ahead of time to allow for a smoother implementation process. The utility can follow as much as or as little of this checklist as needed before reaching out to a vendor. Example forms from vendors are included at the appendix.

Acronyms

GFS Global Forecast System

GPS Global Positioning System

HRRR High Resolution Rapid Refresh

KML Keyhole Markup Language

NBM National Blend of Models

NOAA National Oceanic and Atmospheric Administration

NWS National Weather Service

QA Quality Assurance

SCADA Supervisory Control and Data Acquisition

SLR Static Line Rating

TASE Telecontrol Application Service Element

Steps for GETs Location Identification

Check the following are completed for high-level tasks

DLR Implementation

- ☐ Define Use-cases for Control Room Implementation and Business Planning
- ☐ Identify Current Static Ratings
- ☐ Gather Historical Weather Data
- ☐ *Optional: Gather Historical Forecast Data
- ☐ Gather Historical Transmission Line Data and Load Profiles
- ☐ Calculate Historical DLR Ampacity
- ☐ Identify Congested or N-1 Lines that DLR > SLR or DLR < SLR
- ☐ Revise Static Rating Assumptions if Warranted
- ☐ Identify Maximum DLR Limit (% of SLR, voltage limit, stability limit, transformer limit)
- ☐ *Optional: Identify Forecasting Error and Assess Risk Tolerance
- ☐ Additional Considerations

PFC Implementation

- ☐ Define Use-cases for Control Room Implementation and Business Planning
- ☐ Identify Congested Elements or Important N-1 Lines on System
- ☐ Identify Substations Where PFCs can be Placed to Move Power off Congested Lines
- ☐ Use Power Flow Modeling of PFCs to Determine Optimal Placement
- ☐ *Optional: Use Power Flow Modeling of PFCs to Determine Optimal Placement with DLR
- ☐ Additional Considerations

Detailed DLR Implementation

Use each step to document details

1. Identify Current Static Ratings.

Collect data for SLR assumptions and conductor properties

Conductor Types/Sizes/Resistivity	
Maximum Conductor Temperature	
Seasonal Ratings	
Ambient Temperature	
Wind Speed/Direction	
Solar Irradiance	
Conductor Emissivity	
Conductor Absorptivity	

2. Gather Historical Weather Data.

Identify sources and gather as much as possible for 2+ years, 10 if attainable. Need wind speed and direction at 10 meters, temperature, and solar irradiance. Many stations don't have solar, utilize IEEE 738 time of day solar calculation for substitute. Most vendors have API access for this data.

Utility Data (at least 1 of 3)	
Local Data (at least 1 of 3)[1]	
NWS Data (at least 1 of 3)[2]	
Run QA Testing, Eliminate Bad Data	
Compare with Static Assumptions	

1 Example database: https://mesowest.utah.edu/ ; https://wrcc.dri.edu/wraws/

2 Example database: https://registry.opendata.aws/noaa-isd/ ; https://www.weather.gov/ffc/archives

3. *Optional:* Gather Historical Forecast Data.

Utility Collected Data (at least 1 of 3)	
Private Entity Collected Data (at least 1 of 3)	
NOAA Archive Data (at least 1 of 3)[3] (HRRR/GFS/NBM models)	

4. Gather Historical Transmission Line Data and Load Profiles.

Gather Load Data for Same Intervals as Weather Data	
Identify Congested Lines	
Obtain GIS to Calculate Line Azimuths	
Azimuths Compared to Prevailing Winds	
Conductor Heights	

5. Calculate Historical DLR Ampacity Using IEEE 738 Standards.

Calculate Weather Observation DLR	
*Optional: Calculate Forecasted DLR	
Apply Moving Average of Interest (Typically 15 Minutes)	

6. Identify Congested or N-1 Lines that DLR > SLR.

N-0 Congested Lines for DLR>SLR	
N-1 Congested Lines for DLR>SLR	
Other (e.g. DLR < SLR)	

3 Example database: https://registry.opendata.aws/collab/noaa/

7. Revise Static Rating Assumptions if Warranted

Updated Ambient Temperature	
Updated Solar Irradiance	
Updated Wind Speed	
Seasonal Ratings	

8. Identify Maximum DLR Limit.

Percentage of DLR limit can be arbitrary and based on risk of avoiding conductor overage temperature

Voltage Limits	
Stability Limits	
Transformer Limits	
Percentage of SLR Limit	

9. *Optional: Identify Forecasting Error and Derate Ampacity Based on Risk Tolerance.

Calculate Forecast Error	
Clip Forecast by Max DLR	
Derate to 90–99 Percentiles	
Determine Acceptable Risk Tolerance of the Utility to Select Derating Values	

10. Define Use-cases for Control Room Implementation and Business Planning[4].

Example cases:

- Operator Scenarios (i.e., N-1)
- Business Planning and Operations
- Day Ahead Market
- Western Energy Imbalance Market

11. Additional Considerations.

- Communications Needs
- Hardware Needs
- Cybersecurity Needs[5]
- Control Room integration Needs
- Critical Span Identification

4 https://www.osti.gov/biblio/1975845

5 https://inl.gov/content/uploads/2024/03/Cybersecurity-Considerations-for-Dynamic-Line-Rating-Deployment.pdf

Detailed PFC Implementation

Use each step to document details

1. **Identify Congested Lines or Important N-1 Lines on System.**

Congested Lines	
N-1 Lines	

2. **Identify Substations Where PFCs can be Placed to Move Power off Congested Lines. Placement of Large Equipment may be Necessary.**

Substations for Congested Lines	
Substations for N-1 Lines	
Accessible substations for Large Equipment for Congested Lines	
Accessible Substations for Large Equipment for N-1 Lines	

3. **Use Power Flow Modeling of PFCs to Determine Optimal Placement[6].**

Adjust Model to Handle PFCs	
Determine Maximum Number of PFCs Available	

4. ***Optional: Use Power Flow Modeling of PFCs to Determine Optimal Placement with DLR.**

Modify Model for Variable Ampacity	
Use Results from DLR Over Same Timespan as Before	

6 https://cigre-usnc.org/wp-content/uploads/2024/06/Optimized-Power-Flow-Control-Device-Siting-with-Coupled-Production-Cost-AC-Powerflow-Modeling-Paper.pdf

5. Define Use-cases for Control Room Implementation and Business Planning.

Examples include

- Operator Scenarios (i.e. N-1)
- Business Planning and Operations
- Day Ahead Market
- Western Energy Imbalance Market

6. Additional Considerations.

- Communications needs
- Hardware needs
- Cybersecurity needs
- Control Room integration needs

Appendix A: Example Form 1

Category	Information Items
Geographic Information	a. Terrain data (10meter or 30meter digital elevation maps) b. Surface roughness data (ground cover, land use, tree height for forest) c. Transmission line structure coordinates (lat/long or UTM, with specific projection specified) d. Typical distance of the conductor spans mid/low point above ground
Time-Series Data	a. Historical weather data b. Historical load data c. Extreme weather events to be aware of d. Weather station data access
Electrical System Information	a. One-line electrical drawings of the system (specific connections each line(s) to be studied connects into) b. Line voltages c. Conductor type details d. Conductor configuration details (single or bundled) e. Conductor minimum distance above ground
Operating Thresholds	a. Maximum conductor temperature b. Maximum emergency conductor temperature with duration c. Maximum operating current (MW or MVA is acceptable) d. Maximum emergency operating current e. Seasonal rating dates (annual, summer-winter, summer-fall-winter-spring, or other)
Communications	a. Known issues/concerns from previous DLR systems b. Known issues/concerns for communication systems c. Line of site concerns d. Cell coverage concerns e. Previous use of successful/unsuccessful communications protocols f. Access to hardwired communications

Appendix B: Example Form 2

* **If a project involves multiple electrical circuits/lines, the information must be provided for each line circuit in a separate file.**

General Information		
Customer Name		Utility or user company name
Customer Code/Acronym		Customer short identifier (6-10 characters) - Will behind the line ID - cannot be changed later.
Line Name		The line name, as used in day-to-day communications between project managers.
Line Identifier		The line identifier. Customer short identifier (6-10 characters), ideally the TASE.2 / SCADA line identifier.
Line Voltage [kV]		The nominal voltage in kV
Number of Sub-conductors		The number of sub-conductors if the line is a bundle.
Maximum Conductor Temperature [°C]		The maximum permanent conductor temperature.
Summer Seasonal Rating [A]		The line's summer seasonal rating.
Line Maximum Rating [A]		This is the maximum permanent current that the sensor must handle. This information is needed to dimension the current transformer (CT).
Conductor Name		If multiple conductors, please specify each one and their tower identifiers in remark section.
Conductor Diameter		This information is needed to manufacture the conductor clamps. (Can NOT change in future)
Number of Sensors		Number of sensors for this line
Is Ice Detection embedded?		If Ice Detection is embeded and part of the scope of project/contract to deliver the sensors with ice detection

Expected Delivery Date		Utility's expected delivery date.
Expected Installation Date		If already utility decided the installation date.
KML file of line with tower and sub-stations locations		Please attached a Google Earth KML file with the location of the towers and sub-stations.
Customer Project Manager (Name/email/ phone)	Name	
	Email	
	Phone #	
	Date of filling the form	

Seasonal Rating					
Period Name	Period Name like (Summer, Winter, …)				
Start Date	Start Day for this Season				
Stop Date	Stop Date for this Season				
Seasonal Limit	Seasonal Limit in [A]				
Maximal ambient Temperature	Max Ambient Temperature of this season in [°C]				
Minimum Perpendicular Wind Speed	Min Perp. Wind Speed for this Seasonal Rating				
Solar Radiation	Solar Radiation for this Seasonal Rating				

Add one new column to this table for each seasonal rating.

Emergency Rating		
If Transient Calculations are part of the contract, please fill in the Emergency Ratings that your utility has.		
10 min Emergency Rating	10 min Emergency Rating of the Line	
15 min Emergency Rating	15 min Emergency Rating of the Line	
20 min Emergency Rating	20 min Emergency Rating of the Line	
30 min Emergency Rating	30 min Emergency Rating of the Line	
Remarks:		

Conductor Information		
Conductor Name		Conductor Name
Diameter		Diam [mm]
Cross Section area		CrossSection [mm^2]
Section (Steel)		SectionS [mm^2]
Section (Aluminum)		SectionAl [mm^2]
Mass per unit length		Mpl [kg/m]
Young Modulus		YoungModulus [N/mm^2 = MPa]
Thermal expansion coefficient		Tec [1/K] ex. 2.30E-05
Temperature coefficient of resistance		Tcr [1/K] ex. 0.004
Resistance @ reference temperature		Rref [Ohm/km] Reference temperature is supposed to be 20°C
Emissivity		Emissivity - Defaut: 0.7
Absorptivity		Absorptivity - Default: 0.9

Span Information			
Reference of Span	Span name		
Reference Conductor	Conductor name for this Span		
Sensor ID	See number on the unit.		
Span Length	Span Length [m]		
Orientation of Span	North=0° and East=90°. In range [0,360] [deg]		
Altitude of Installed Sensor	Approximative ground altitude of the installed sensor to compute solar radiation		
Longitude of Installed Sensor	[GPS coordinate]		
Latitude of Installed Sensor	[GPS coordinate]		

Add one new column to this table for each monitored span.