NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Technical Brief on Data Collection Recommendations for Distributed Energy Resources

The Distributed Energy Resources Task Force (DERTF) of the Essential Reliability Services Working Group (ERSWG) previously produced a report on *Distributed Energy Resources: Connection Modeling and Reliability Considerations*[1] in December 2016. The report emphasized the need to understand the data that should be collected and shared at the interface of the distribution and transmission systems to ensure reliable operation of the grid. Since issuing that report, the task force continued to evaluate the entities and roles that are involved and the information that may need to be collected and shared. This document presents the results of this evaluation and makes recommendations for ongoing activities.

Background

Distributed energy resources (DERs) are resources on the distribution system that produce electricity and are not otherwise included in the formal NERC definition of the Bulk Electric System. Common DER installations are residential rooftop solar, commercial/industrial/community solar, utility-scale projects on the distribution system, distributed wind, microgrids, and small cogeneration projects. DERs can be further categorized in various ways, such as their degree of being variable or dispatchable (both of which may include a range of widely differing operating characteristics) or as being utility-scale (U-DER), retail-scale (R-DER), or residential-scale (which have different sizes, configurations and locations on the distribution grid).

As the penetration increases and DERs become a significant energy resource, the interconnectedness of the grid necessitates adequate knowledge of these resources to maintain the reliable operation of the bulk power system (BPS). Historically, many distribution load forecasts have netted DER production with feeder loads without accounting for DERs separately, which was reasonable given their minor impact to the BPS. However, significant DER levels in some areas, and projections for significant DER growth in many others, now necessitate an improved understanding and sharing of information about DERs for the planning and operation of the BPS.

Roles and entities[2] that are affected by DERs include the following:

- Balancing Authorities (NERC Glossary Term)
- Distribution Providers (NERC Glossary Term)

[1] December 2016 Distributed Energy Resources: Connection Modeling and Reliability Considerations

[2] Entities that are defined in the NERC Glossary of Terms are generally capitalized in this document. See Glossary of Terms

  - Distribution operators (General Industry Term)
  - Distribution system protection engineers (General Industry Term)
  - Distribution planners (General Industry Term)
- Transmission Operators (NERC Glossary Term)
- Transmission Planners and Planning Coordinators (NERC Glossary Terms)

Each of these roles and entities will require appropriate DER information to reliably perform their particular functions in the BPS. The transfer of this data and information may be bidirectional. For example, while certain information may be provided by distribution providers to those responsible for the BPS, other information and guidance may be provided by the entities responsible for the BPS to distribution providers. It is noted that many distribution providers are not NERC-registered entities as they do not meet the registration requirements. A non-registered entity is not subject to NERC Reliability Standards, and this report is not proposing changes to registration requirements or standards, but rather that a cooperative exchange of information will be prudent and beneficial to all parties.

Particular attention must be given to the transmission-distribution (T-D) interface. Whereas traditionally power flow has been from the transmission to the distribution systems, it is possible for active power to flow from the distribution system to the transmission system under certain conditions with the deployment of DERs on the distribution system. This shift in the active power flow direction and level, due to the operation of the DERs, is critical to the listed entities.

This technical brief describes a non-comprehensive set of data that may be useful for each industry group to obtain. However, there may not be a need for all data to be collected immediately, as the need may be based on the type, amount, or operational nature of connected DERs. Each industry group will need to evaluate their needs, and in coordination with other entities, clearly define and obtain the necessary information in order to accurately model and reliably operate the BPS.

Balancing Authorities

A Balancing Authority (BA) is responsible for real-time load and generation balance, frequency control, maintaining adequate operating reserve (including contingency reserve), and responding to sudden losses of generation. If not monitored by the BA as a generation resource, DER production modifies the load as seen by the BA. Generally, as DER production increases, BA load decreases. Knowledge of DER output and operating characteristics is required to adequately forecast BA load and operating and contingency reserve levels. For example, during the summer or in warm weather climates, distribution load generally increases through the day, peaking late in the afternoon, and then decreases as the sun sets. However, generation from solar DERs will generally increase through the morning as the sun rises (lagging behind the morning peak) and decrease later in the afternoon as the sun sets. This results in the BA adding generation resources to match rising load in the early morning, reducing or removing resources during the afternoon as DER solar power is generated, and then adding resources again in the late afternoon and evening as the solar DER generation decreases while distribution load remains high. This may create situations where the BA must follow a faster BA apparent load increase in the evening than they would have otherwise observed. There

may be seasonal variations in these patterns, such as BAs that see lower midday customer load during the winter while also having a strong solar resource.

DER patterns may also be altered due to evolving tariffs or the aggregated uses of DERs, such as by the self-dispatched use of DERs to reduce demand charges, respond to price signals, or provide various grid services with aggregated DER resources. In some cases, aggregators of DER resources may be able to assume some of the information reporting responsibility.

BA operations can be enhanced with the following:

- Accurate distribution load forecasts on an hourly (or shorter) basis at each load bus
- Accurate DER forecasts on an hourly (or shorter) basis at each load bus
- Accurate net load forecasts on an hourly (or shorter) basis at each load bus
- DER sensitivity to changing weather (cloud cover, irradiance, etc.)
- DER aggregation on both a substation or wider area basis
- DER active power capability on both a substation and aggregated basis
- DER resource ramp rates in watts per minute (both ramp down and ramp up)

Distribution Operators

Distribution operators are engaged in a wide range of activities. These vary by operating utility, local regulations, operating voltage (generally less than 100 kV), and organizational structure. In general, distribution operations refer to the following:

- Voltage regulation—tap changing regulators, switched capacitors, and fixed capacitors
- System protection—feeder breaker, mid-line recloser, and fuse coordination
- Switching practices including prearranged and emergency switching, energized work permits (or hot line tags) and clearance
- Load transfers between feeders and substations
- Fault Location, Isolation, and Service Restoration (FLISR) schemes—includes automatic sectionalizing, restoration and feeder reconfiguration
- Customer owned generation used as backup or operated in parallel

Distribution systems are traditionally designed to be operated as load connected to a source, where power flows from the transmission-distribution transformer to the connected load. Traditionally, there are few, if any, provisions for power to flow from the distribution-connected load to the transmission-distribution transformer. Voltage regulators are configured to operate based on unidirectional power flow while maintaining adequate voltage for all loads under all load conditions. Capacitors (switched and fixed) are placed on the feeder to correct the system's power factor and to support the voltage as necessary for the

unidirectional power flow to customer loads. Distribution customer service voltage levels must be maintained within the defined tolerances.[3]

The output of DERs affects net loading on a distribution feeder, which consequently affects the voltage control scheme for the feeder. With sufficient DER generation on the feeder, power may flow from the feeder to the transmission-distribution transformer. Many distribution systems are not configured for this type of operation, which may require significant equipment, hardware, and software changes to accommodate bidirectional power flow. Therefore, knowledge of the DER resources and their operating characteristics (e.g., passive or active voltage and frequency control, island capability, etc.) is essential to the safe and reliable operation of the distribution system.

Distribution operations can be enhanced with the following:

- Accurate location, capacity, type, and capabilities of DER
- Accurate DER production forecasts on an hourly basis
- DER sensitivity to changing weather (cloud cover, irradiance, etc.)
- DER excitation control mode (e.g., fixed power factor, fixed reactive power, Volt-VAR, Volt-Watt, frequency-watt, etc.) and related settings
- DER response to abnormal voltage and frequency
- DER capability to be a fault current source
- DER isolation schemes
- DER capability to sustain an island

Distribution System Protection Engineers

Distribution system protection equipment and schemes are relied upon to clear abnormal conditions, such as short circuits (faults) and open phases. This is essential for public safety and to protect the distribution equipment and connected loads from abnormal conditions. Protection systems are designed to remove the faulted component from the feeder while maintaining service to the remainder of the feeder. Feeder protective devices consist of feeder breakers, fuses, and mid-line reclosers. The transmission-distribution transformer can be protected by circuit switchers, circuit breakers, or high-side fuses. Distribution systems are normally operated radially from the transmission-distribution transformer to the connected load or, stated differently, operated with the assumption of having a single transmission source serving distribution load.

From a system protection perspective, significant DER penetrations can alter the assumptions under which protection systems were designed and affect current and future protection schemes, therefore the following information may be needed:

- Accurate location, capacity, type, and capabilities of DERs

[3] These voltage tolerances are defined in the Institute of Electrical and Electronics Engineers (IEEE)/American National Standards Institute (ANSI) C84.1 Standard, and are typically +/- five percent.

- DER response to abnormal voltage and frequency (inverter control modes)
- DER capability to be a fault current source (such as maximum current) including short circuit modeling data
- DER capability of islanding
- DER reconnection requirements—island or individually

Distribution Planners

Distribution planners are tasked with planning a distribution system that can be operated safely and reliably. Distribution planners assist in the creation of protection schemes. This information will help to ensure that the appropriate equipment and protection schemes are installed. The data requirements for this industry group are similar to those of the distribution operators.

For distribution planner functions, the following information may be needed:

- Accurate location, capacity, type, configuration and capabilities of DERs
- Accurate DER production forecasts on an hourly basis
- DER response to abnormal voltage and frequency
- DER capability to be a fault current source

Transmission Operators

Transmission Operators are responsible for real-time situational awareness of the transmission system and responses to contingencies. Off-line power flow studies are used for seasonal analysis, outage coordination, and next-day analysis. DERs have a direct effect on loading of the BPS. Transmission system load is often measured at the transmission-distribution transformer where distribution load may be offset by DER generation. This affects many aspects of transmission operations for the following reasons:

- Transmission voltage and power flow vary by system loading.
- Voltage control varies with the transmission system loading.
- Post-contingency conditions are affected by system loading.

For Transmission Operators, the following information may be needed:

- Accurate distribution load forecasts on an hourly basis at each load bus
- Accurate DER forecasts on an hourly basis at each load bus
- Accurate net load forecasts on an hourly basis at each load bus
- DER sensitivity to changing weather (cloud cover)
- Aggregate nameplate capacity of DERs is forecasted at each load bus for each year during the operational planning horizon
- Potential real-time changes in DER production due to weather, time of day, etc.
- Voltage and frequency ride through capabilities of DER (IEEE 1547 abnormal performance categories assignment)
- Category III DER momentary cessation voltage threshold
- Voltage control capabilities (IEEE 1547 abnormal performance categories assignment)

- Frequency control capabilities and settings
- Automatic restoration capability and settings

Transmission Planners and Planning Coordinators

Transmission Planners and Planning Coordinators are responsible for planning a BPS that can be operated reliably and safely. They utilize very detailed models of the BPS system that include the aggregate load components of the distribution system. BPS system planning models explicitly model individual network components, such as transmission lines, transformers, capacitors, reactors, generators, and loads. Model accuracy is necessary to plan a functioning power system. Model data is validated in many ways, including equipment testing and comparison of model performance against actual system events. The system planning model is also used for system operations off-line power flow analysis and components of the planning models may be used in state estimation systems and real-time contingency analysis. Accurate data is essential.

Since DERs are on the distribution system, masking of the impacts of DERs may occur if the distribution load and DERs are netted to calculate or measure a net distribution load. However, netting DERs will not capture response to off nominal frequency and voltages that can occur on the BPS. Large changes in net system load will directly affect BPS performance under pre-contingency, post-contingency, and transient response to disturbances.

For Transmission Planners and Planning Coordinators, the following information may be needed:

- Accurate hourly distribution load forecasts at each load bus
- Accurate hourly DER forecasts at each load bus
- Accurate hourly net load forecasts at each load bus
- DER sensitivity to changing weather (cloud cover)
- DER aggregation on both a substation or wider area basis
- Potential real-time changes in DER production due to weather, time of day, etc.
- Voltage and frequency ride through capabilities of DERs (IEEE 1547 abnormal performance categories assignment)
- Category III DER momentary cessation voltage threshold
- Voltage control capabilities (IEEE 1547 abnormal performance categories assignment)
- Frequency control capabilities and settings
- Automatic restoration capability and settings

Future: Recommendation

While other work of the ERSWG is being completed and transferring to the appropriate subcommittees for ongoing assessments, deployment and analysis of DERs is still evolving. Additional deployment of DERs will broadly affect a wide range of assessments as well as planning and operating practices at both the BPS and distribution level.

The ERSWG recommends that NERC maintain an ongoing DER coordinating group while working with the Operating Committee and Planning Committee to provide broad assistance with DERs and their interactions

with BPS reliability and other NERC activities. Given the emerging nature of DERs and the wide range of potential impacts, a defined industry group will serve as a common point of contact and coordination for future work and assist with consistency in message and language.

Summary and Conclusion

Adequate information about DERs becomes necessary to maintain the reliable operation of the BPS as penetration increases and DERs become a significant energy resource. Traditionally, distribution load forecasts have netted DERs with feeder loads, and this was reasonable given their minor impact at the transmission-distribution interface. However, with the current and future level of DERs in some areas, it becomes necessary to consider the information that may need to be collected and shared.

Many industry groups can be affected by DERs, including Balancing Authorities, distribution providers (distribution operators, distribution planners, and distribution system protection engineers), Transmission Operators, Transmission Planners, and Planning Coordinators. Each will need varying levels of detail, depending on the characteristics of their systems and the level of DER deployment. Particular attention is needed regarding the affects at the transmission-distribution interface. With improved data exchange and collaboration, it will be possible to maintain and improve the planning and reliable operation of both distribution systems and the bulk power system.