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# Impacts and Mitigation of Distributed Energy Resources on Local Utilities

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## SUMMARY

Since the widespread adoption of transformers in the early 1900s, the energy grid has been constructed and designed to bring energy from remote generation facilities through long-distance transmission lines to load centers. Over a century has passed with the energy grid expanding with this architecture. With the growing prevalence of generating sites interconnecting to distribution networks, otherwise known as distributed energy resources (DERs), this architecture can no longer be assumed. Consequently, traditional practices must be re-examined and adapted to the new architecture of the energy grid. Using example projects, this paper aims to highlight the impacts of DERs and requirements that can mitigate these impacts.

## KEYWORDS

Distribution, Distributed Energy Resource (DER), Inverter Based Resource, Interconnection, National American Electric Reliability Corporation (NERC), Federal Energy Regulatory Commission (FERC), Subtransmission, Transmission

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## I. INTRODUCTION

By working on DER projects contracted to Commonwealth Associates Inc. by DER designers and utilities, we have gained firsthand experience studying the impacts of greenfield DERs on existing electrical networks. By reviewing designs and employing power system modeling software, we analyzed the surrounding electrical networks and the interconnecting DERs under likely operating conditions. We also ensured the impacts do not exceed power quality or system stability requirements. This paper identifies and examines the impacts DERs have on the electrical system and what requirements are—or can be—put in place to control them.

## II. DER DESIGN CONSIDERATIONS

Modeling a system is time intensive and can be difficult to accurately complete during the design process as information is in flux. However, there are some considerations that can be accounted for early in the process. In this section I will go over some of these considerations for DER designers, and the utilities.

- **Isolating Transformer Configuration**
  The configuration of the transformer between the DER and the utility is an important consideration. Typically, a Delta/G-Y transformer is desirable to provide higher fault current for grounded faults. A higher fault current increases the ease with which protection devices can detect a grounded fault. As the utility, it is important to ensure DER applicants' plans are reviewed and have the desire transformer configuration. As a DER designer, it is important to know the interconnected utilities desired transformer configuration and interconnection voltages to ensure the correct transformers are ordered.

- **Interconnecting Lines**
  It is important to know the capabilities and locations of the existing power lines near the physical DER site. The maximum capacity of the DER is limited by the existing power lines' ampacity. A smaller DER than originally planned may be required due to the expense of upgrading the existing power line. Depending on the type of upgrade and the amount of line that will need to be upgraded, this can cost enough to make a DER uneconomical. In addition to existing power lines, the power line connecting the point of interconnection (POI) and the closest interconnecting line is also important to include into the DER's construction cost.

- **Isolation device**
  During power line repairs or other line work, it must be possible to de-energize the power line. With historic grid architecture, this was enabled by opening the breaker at the substation. However, with DERs, a line can be energized while disconnected from the substation. Utilities should have regulations in place that require DER applicants to install an isolation device, operable by utility personnel outside the DER site, that can de-energize power lines quickly and safely. This can be in the form of a direct transfer trip or a loadbreak switch.

- **Protective Relaying**
  Islanding is when a portion of the grid with generation and loads continues to operate separately from the rest of the electrical system. When done unintentionally, this can create abnormal and unstable conditions. With historic grid architecture, the distance between generation and load centers made it difficult to create an unintentional island. However, with DERs, the distance between generation and load is greatly reduced and

increases the likelihood of creating unintentional islands. To prevent DERs from creating unintentional islands and supplying power to the grid during unstable conditions, utilities typically require DER applicants to have protective relaying that can detect and disconnect DERs under these conditions. All DER inverters should be UL1741/IEEE1547 certified with anti-islanding protection, and have a protective relay with overfrequency, underfrequency, overvoltage, and undervoltage settings.

- **Single-Phase Conditions**

It is possible for DERs to be installed on feeders with the potential to operate with single-phase conditions. The DERs should be required to detect single-phase conditions—and either disconnect from the electrical system—or be able to produce single-phase power.

- **Communication Circuit**

To meter DERs to determine generation conditions, load conditions, and payment to the DER owners a communications circuit is required.

## III. SAMPLE DER PROJECT

Commonwealth was contracted by a utility that was inundated with applications to interconnect photovoltaic DERs on their 34.5 to 69 kV subtransmission system. Commonwealth was engaged to determine if the applying DERs met the necessary utility requirements to ensure power quality, and system stability.

- **System Impacts**

Commonwealth used an electrical power flow analysis tool called CYME to model the existing electrical system and analyze the impacts of these potential DERs.

**i. Voltage Regulation**

Voltage regulators raise or lower voltages so that the closest and furthest customers on the feeder do not experience voltages that would damage electrical equipment. This is typically considered less than 88% of nominal or greater than 110%. Typically, this is done by monitoring the voltage at the substation and raising voltage to set levels, as voltage decreases while power travels farther from the voltage regulator. However, DERs increase voltages around where they interconnect. This potentially leads to a voltage regulator increasing or decreasing voltages to damaging levels.

To ensure voltage stayed within the acceptable range the model was analyzed at all potential DER generation levels of both real and reactive power from 0% to 100%. Simultaneously, loads were scaled from 0% to 150%. This was to study that an event, such as a clouds passing over the site that may cause generation to drop and raise, would not cause abnormal voltage conditions for customers at any expected amount of loading.

Some reviewed DERs did show potential to cause system voltages to stray outside of acceptable levels. These often could be rectified with voltage regulator setting changes. A few DERs required additional voltage regulators to be added to the system to maintain acceptable voltages.

### ii. Power Flow

Power historically flows in one direction. Power starting from a generation site is added to the transmission system feeding a subtransmission and/or distribution system to deliver power to loads. During times of decreased loading and high generation, DERs can provide power from the subtransmission/distribution system to the transmission system. This is considered a backflow condition that can cause protection misoperations or equipment damage.

The system power flow was analyzed with 20% of the expected load to show what equipment would experience a backflow condition during light loading. Many of the DERs indicated they would create backflow conditions into the substation. Equipment that would experience backflow conditions was investigated and reviewed to determine if replacements or settings updates were required to prevent misoperations and equipment damage. A backflow condition onto the 138 kV system was undesirable as it would require agreements between the utility and the transmission company to be adjusted to allow for buying and selling power.

In addition to backflow conditions, the utility system would also have to ensure the utility system could withstand the increased power flow from the DERs. A power flow analysis was performed with the maximum rated capabilities of the applying DERs and no load. This ensured all equipment was properly rated for the worst condition. Existing powerlines, transformers, and protection devices were often unable to withstand the increased power flow. To interconnect these, under-rated equipment would need to be replaced or the offending DERs would need to reduce their planned capabilities.

It should also be noted that on occasion, multiple DERs applied to interconnect on the same feeder. Each DER individually did not cause power flow concerns, but they would surpass the system rating and/or cause backflow conditions when combined.

### iii. Reactive Power Flow

Rotating generation provides reactive power passively. As voltage or frequency becomes out of step with the rotating generator, the inertia of the machine produces reactive power as the machine matches the state of the system. Inverter based resources such as solar do not passively generate reactive power and must be able to produce between power at a power factor of 0.95 lagging and 0.95 leading to meet FERC order 827 and the requirements of the utility.

The reactive power capabilities of DERs were modelled by including reactive power losses behind the meter such as transformers. The capability curves of the inverter were utilized to determine the maximum power generation in both lagging and leading conditions. DERs that were unable to meet this requirement required reactive power support in the form of capacitors or an inverter with greater reactive power capabilities.

### iv. Short Circuit Current

Short circuit current historically decreases as the distance from the substation increases. This allows equipment at the end of the feeder to be rated for less short circuit current than the equipment in the substation. However, DERs can increase the possible short circuit current around the point of interconnect.

The DER short circuit contributions and system short circuit current were modelled to analyze the short circuit current equipment would see. Many DERs increased the short circuit contributions above the equipment's withstand rating. This required replacement of this equipment with equipment of higher ratings.

## IV. CONCLUSION

DERs have many benefits, but they need to be studied in detail to ensure they don't adversely affect the power system. An experienced engineering firm can help by ensuring that the DER can be installed at a specific location, meeting the necessary requirements and regulations, and calculating the likely costs and network upgrade costs before getting too deep into the project.