Dominion Energy Virginia / North Carolina

Interconnection Parameters for Distributed Energy Resources

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1 Scope

The scope of the Interconnection Parameters for Distributed Energy Resources Guide (Guide) is to provide technical background and guidance concerning the interconnection of Distributed Energy Resources (DER) for the primary purpose of exporting energy onto Dominion Energy Virginia / North Carolina's electric distribution system, referred to in this guide as the Electric Power System (EPS). The Guide includes details of Dominion Energy's DER General Study Process and Parameters, and DER General Interconnection Parameters. The Guide also discusses Wind Turbine Generation (WTG) and Energy Storage System (ESS) Interconnection Parameters. Furthermore, DER grid support and ride-through capability requirements as defined in the IEEE Std. 1547-2018 are discussed within.

While the Guide largely focuses on electric generating facilities that have the characteristics of being intermittent and/or inverter-based (i.e., wind, solar, or battery energy storage), the requirements in this Guide apply to all exporting DER, regardless of the technology being employed, with a rated output capacity of 24 megawatts (MW) or less (per application), excluding net metering. A Guide for Net Metering is listed elsewhere. For DER larger than 24 MW, further study will determine if interconnection can be accommodated. The interconnection parameters described in the Guide are based, as applicable, on Good Utility Practice, industry standards, the North Carolina Utilities Commission (NCUC) Interconnection Rules and Procedures, and the Virginia State Corporation Commission's Regulations Governing Interconnection of Small Electric Generators which define and establish standardized interconnection and operating requirements for the safe and reliable operation of the EPS and DER.

Generation output at unity power factor is used as the basis for the establishment of the technical requirements described in this Guide unless specified otherwise. Any output capacity discussed in this Guide will be stated as MW unless specified otherwise.

Estimated facilities costs for typical DER upgrades are attached as Appendix D.

1.1 Disclaimer:

The information contained within this Guide, including any standards, guidelines, criteria, or requirements referenced therein or included in the Appendices, is intended to be used for information purposes only, is provided "as is" without representation or warranty of any kind, express or implied, and is subject to change. If there are any future changes to the requirements in this Guide, Dominion Energy will consider retaining the parameters utilized to identify Interconnection Requirements for all DER interconnection requests for which a Feasibility Study Agreement or a Combined Study Agreement has been executed by the time of the change. For any DER interconnection requests in the queue for which a Feasibility Study Agreement or a Combined Study Agreement has not been executed by the time of the change to the Guide, any updated requirements for interconnection would apply.

Dominion Energy is not responsible for the user's reliance on this Guide, or for any erroneous or misleading material. Dominion Energy may revise or withdraw this Guide at any time at its discretion without notice. It is the user's responsibility to ensure that it complies with all of Dominion Energy's current interconnection and operating requirements. To the extent that the information in this Guide is inconsistent with the Dominion Energy tariffs or agreements, the Dominion Energy tariffs or agreements, as applicable, shall control. Finally, this Guide is non-binding and confers no rights.

2 DER General Study Parameters

Dominion Energy's DER General Study Parameters for all DERs consist of a Preliminary Review phase, a Feasibility Study phase, a System Impact Study phase, and a Facility Study phase. Different regulatory area may have various levels of interconnect classification (Level 1, Level 2, Level 3, etc.) and these classification levels may require different levels of study; some study phases may be combined and/or eliminated. The Preliminary Review phase provides prospective DER developers information early in the interconnection study process to help DER developers decide whether to pursue the proposed DER interconnection. Information resulting from the Preliminary Review phase includes the potential impact the proposed interconnection may have on distribution substation transformer capacity and distribution circuit capacity. These potential distribution and substation upgrades are discussed before any detailed engineering study is performed that may eventually lead to the identification of other or additional required upgrades to support the proposed DER. The DER General Study Parameters sections in this Guide provide a detailed description of the following:

- Dominion Energy's DER Interconnection Study process in general. (see section 2.1)
- DER Interconnection Study Parameters in general and the criteria that guide them, such as Power Quality Requirements, Rapid Voltage Change (RVC), Transformer Inrush requirements, and Harmonics. This section also discusses the basis for other power quality mitigations. (see section 2.2 and associated subsections)
- Other important requirements that guide DER study parameters and include:
    - Express Circuit Requirements (see section 2.3 and associated subsections)
    - Transformer Loading Limit Requirements (see section 2.4)
    - Circuit Loading Limit Requirements (see section 2.5)
- Dominion Energy's approach to the DER grid support and ride-through (see section 2.6 and 2.7 respectively)
- Equipment reviews performed throughout the DER study process (see section 2.8)

The DER General Study Parameters section in this Guide provides a detailed description of the physical interconnection of the DER with Dominion Energy's EPS. The section focuses on the Point of Interconnect (POI) and associated attachment facilities, and includes the following:

- Dominion Energy's DER Interconnection Generator Step-up Transformer Requirements (see section 3.1)
- Interconnection parameters for DER less than 1 MW (see section 3.2)
- Interconnection parameters for DER above or equal 1 MW (see section 3.3)

Finally, most of the study parameters associated with the requirements described in the sections and subsections below are applied throughout the electric distribution feasibility and impact studies.

2.1 The Interconnection Study Generally

Any DER that will operate in parallel with the EPS is required to meet applicable standards for interconnection and be certified to applicable testing standard(s). These standards include, but are not limited to, IEEE Std. 1547 and UL 1741 standards. Section 6 of this Guide includes a non-exhaustive list of applicable guides, codes and standards, state jurisdictional rules, and procedures applicable to the interconnection of DER.

IEEE Std. 1547-2018 defines a DER as "a source of electric power that is not directly connected to a bulk power system. DER includes both generators and energy storage technologies capable of exporting active power to an EPS" (IEEE, 2018, p. 22).

For any exporting DER connecting to Dominion Energy's EPS, regardless of its technology, the determination of whether the DER can safely and reliably operate in parallel with the EPS depends on several criteria applied at different phases of the DER interconnection review and studies. These include but are not limited to the impact of DER on safety to the public, utility employees and utility equipment, on transformer and circuit loading and/or capacity, on conductor thermal rating, on voltage profile or power quality, on protective device coordination, and other criteria as described in the sections 2.2 through 2.8 below.

In a typical interconnection study, the export and/or import loading limit associated with a generator interconnection will be determined in the preliminary review. The loading limit is dependent upon the size/type of the DER, the rating and capability of the applicable distribution facilities, and associated control equipment. Applicable distribution and substation facilities include but are not limited to the following devices: substation transformer, load tap changer, circuit conductor(s), substation and/or line regulator(s), distribution pole/pad-mounted transformer(s), breaker(s), line recloser(s), and fuse(s). Please refer to sections 2.4 and 2.5 for additional information on loading limit calculation.

The goal of determining a loading limit is to ensure that the generation facility does not cause the rating of the distribution system equipment to be exceeded under all operating conditions. Additionally, the DER study process may include detailed evaluations to ensure the following distribution and substation equipment ratings are not exceeded:

- Maximum voltage
- Basic Impulse Limit (BIL)
- Short circuit ratings/limits

Dominion Energy considers any additional interconnection equipment or device that is added to ensure compliance with some or all of the interconnection requirements as part of the DER's interconnection facilities. The additional equipment or device will need to meet the interconnection requirements as defined in the IEEE Std. 1547-2018.

The sections below provide additional guidance on the general parameters considered by Dominion Energy during the DER interconnection study process. While the below sections provide guidance on the parameters that have the most impact on the outcome of the study process, they do not constitute an exhaustive list of all applicable study parameters.

2.2 Interconnection Study Parameters Generally

Dominion Energy performs voltage studies on all proposed DER sites using a distribution power systems simulation platform called Synergi Electric. Existing circuit models for Dominion Energy's EPS are used and the proposed DER site is added to the model. Power flow studies are performed and the DER power output is varied from full output to no output to evaluate the worst-case voltage changes to the EPS (often called "flicker"). All proposed DER interconnections are currently studied first at a fixed power factor, typically unity (1.0 PF), which is considered the base-case scenario for all DER regardless of the technology and/or the reactive or voltage support capability. Smart inverter functions (such as a power factor adjustment, a watt-var schedule, a volt-var schedule, or a ramp rate) may also be proposed, in limited circumstances, to mitigate power flow concerns and/or voltage concerns caused by the addition of the proposed DER, when applicable. The specific timing requirement for a proposed project's ramp rate (if needed to mitigate violations) will be determined during the feasibility study and will depend on the existing time delay of the voltage control device regulating the circuit and/or transformer feeding the proposed DER interconnection site. Additional information on power quality, transformer inrush, Rapid Voltage Change (RVC) and harmonics requirements are provided in the subsections below.

2.2.1 Power quality requirements

The goal of the DER interconnection study process is to ensure that any DER connecting to the EPS does not impact the power quality of Dominion Energy's system or other connected customers. Important power quality criteria evaluated during the DER interconnection study process include the following:

- Ensuring that voltage dip/rise or the Delta change in voltage does not exceed 3% of nominal voltage due to rapid changes in DER output
- Ensuring that harmonic distortion levels do not exceed limits as defined in IEEE Std. 519-2014 and IEEE Std. 1547-2018
- Ensuring simulated flicker on the EPS is maintained within the requirements defined in IEEE Std. 1547-2018

2.2.2 DER system's RVC and transformer inrush requirements

IEEE Std. 1547-2018 requires DER not to cause voltages to exceed 3% of nominal and 3% per second averaged over a period of one second when the Point of Interconnection (POI) is at medium voltage. Medium voltage is typically defined as voltage above or equal to 1 kV but less than or equal to 35 kV.

For a POI at low voltage, which is defined as voltages 1000 V and less per IEEE C62.41.2, IEEE Std. 1547-2018 requires DER not to cause voltages to exceed 5% of nominal and 5% per second averaged over a period of one second.

An excessive amount of RVC, even if it is infrequent, can have a negative impact on power quality. For example, Dominion Energy customers with voltage sensitive processes or equipment have in the past experienced significant disruption due to RVC. Thus, Dominion Energy requires RVC to be limited to specific levels as described above and as established in the IEEE Std. 1547-2018.

RVC can be the result of inrush occurring during DER transformer energizations. In some cases, transformer energization can lead to severe harmonic voltage distortion due to circuit conditions ultimately leading to resonances. As part of the interconnection study process for DER, Dominion Energy performs an inrush study for all DER sized 3 MW and above connecting at 23 kV and 34.5 kV. An inrush study is also performed for all proposed DER sized 1 MW and above connecting at 12.5 kV, 13.2 kV, and 13.8 kV. The transformer inrush study informs the DER developer of the potential for RVC problems based on its system design and provides recommendations on how to mitigate RVCs. The DER developer's compliance with the RVC requirements as defined by IEEE Std. 1547-2018 will ensure proper limitation of RVC caused by the DER. The RVC requirements will not apply to infrequent events such as switching, unplanned tripping, or transformer energization that are related to commissioning, fault restoration and maintenance, and other infrequent events. However, some typical and/or regular operational practices that cause RVC will need to be mitigated by the DER owner.

2.2.3 Harmonics requirements

Dominion Energy has identified several areas of concern related to harmonics for DER. Harmonics can be generated by several components of DER, including soft start units, power electronics, transformer energization, and saturation. The following subsections describe the harmonic study process and some mitigation solutions utilized when harmonic issues are identified.

2.2.3.1 Harmonics study process

Presently, Dominion Energy installs power quality meters to monitor harmonics. These are placed at the POI and at the substation before the DER is energized to record “background” harmonics. This allows Dominion Energy to study the harmonics that are contributed by the DER prior to energization and once energized, and the substation power quality metering tracks the total harmonics of all DER on the transformer and all connected circuits.

All equipment that can produce harmonics should meet regulations limiting Total Harmonic Distortion (THD) to limits as defined in the latest revision of IEEE 519. If the power quality meters discussed above reveal significant issues at a DER site, the DER developer must mitigate the harmonics as described in the subsection below.

In addition to monitoring THD, a harmonic resonance study will be performed on certain DER. This study will be typically performed for WTG interconnects with several miles of underground cable in WTG systems (actual mileage to be determined through study). Additionally, a harmonic frequency analysis will be run for the feeder with and without the WTG facility to determine if any new harmonic resonant points will be added to the feeder, or if any existing resonant points will be shifted.

2.2.3.2 Harmonics mitigation

If it is determined that a new or shifted resonant point will coincide with existing harmonics on a feeder and THD is increased past established limits, the DER developer will typically be required to install harmonics filters to prevent other customers from being exposed to damaging harmonic levels. Other harmonic mitigation techniques may be explored upon request and will be subject to review/study and approval by Dominion Energy.

2.2.4 Requirements for power quality mitigation

There may be instances when Dominion Energy may require installation of additional devices to help mitigate power quality impacts to the system. Those mitigation techniques include but are not limited to the addition of Distribution Static Synchronous Compensators, or D-STATCOMs, to reduce the effects of harmonics and voltage fluctuations.

2.2.5 Circuit configuration requirements

All proposed DER must connect to a three-phase line and cannot connect to a single-phase tap off a distribution line. If a proposed DER is located on a single-phase tap downline of the main three-phase line, that tap will need to be reconductored/reconfigured to a three-phase line. Additionally, it is Dominion Energy’s policy to connect all DER at the distribution substation bus voltage. A large percentage of our Customers are served from 34.5 kV sourced circuits; however, on Dominion Energy’s distribution system, it is common for distribution lines to be operated at one voltage at the substation before stepping down to a different, lower voltage further downline of the substation. The lower voltage systems - 12.5kV, 13.2kV, etc. – are often incorporated into our 34.5 kV system. When a proposed DER is located downline of a step-down transformer, voltage conversion of the line to the substation voltage will typically be required in order to mitigate voltage regulation issues that would occur for customers along the proposed interconnecting circuit. Express Circuit Requirements

2.2.6 Express circuit requirements for Intermittent DER

The following section describes when a DER will be required to connect to an express circuit. An express circuit is a new separate circuit feeder at the substation with direct a path between the substation and the DER POI, typically with limited customers or branches along the path and a limited circuit length. These express circuits are used to limit voltage drops to other customers that could be a large distance away the feeder breaker. The new express circuit can be used for other Dominion Energy customers at the discretion of Dominion Energy because it is not a dedicated circuit. Good utility practice will require installation of a circuit tie, outside the substation fence, from this new express circuit to existing circuits in the area.

Intermittent DER production, such as wind and solar PV, can cause voltage fluctuations throughout a circuit due to the change in energy output of the DER and the time delay of voltage control equipment. This change in energy output negatively affects the power quality of connected customers. Because intermittent DERs present more risk of causing voltage fluctuations, Dominion Energy has established the following standard: any intermittent DER with an output at or exceeding 20% of the associated circuit capacity and located within approximately one (1) mile from the substation shall be connected to an express circuit/feed to avoid customer exposure to the effects of voltage swings, including customers with sensitive equipment. When the DER interconnection study indicates increased risks of voltage swings or other risks affecting a customer's power quality, Dominion Energy may require, at its discretion, an express circuit beyond the one (1) mile threshold. New express circuit feeders will require a new feeder breaker in the substation. This new breaker will be installed on an appropriate transformer in the substation following good utility practice. This new feeder breaker may be installed on a different substation transformer than originally stated during the preliminary review phase and could thus change the substation interdependency of the proposed interconnect.

2.2.7 Express circuit requirements for Energy Storage Systems (ESS)

Given the nature of energy storage systems, which are capable of receiving electric energy from the EPS and storing it for later injection into the EPS in a controlled manner, intermittency is much less of a concern. The output control capabilities make ESS eligible for an exception to the requirements for an express circuit as outlined in section 2.3.1. Specifically, other requirements such as ramp rate control and/or other smart inverter functions may be substituted for the express circuit requirements, upon agreement by Dominion Energy and the DER developer. Such agreements will be identified in the final DER interconnection study results and incorporated in the DER Interconnection Agreement (IA).

These limitations in place of the express circuit requirement can impact an ESS's system performance and/or the ability of the ESS to participate in markets such as the frequency market. Therefore, potential tradeoffs should be considered carefully prior to agreeing to any ESS limitations. Additionally, it is important that the ESS developer clearly indicates its uses/applications for the ESS so that it can be factored in the study/analysis. This is discussed further in Section 5 of the Guide. This will allow the study team to provide information on all the required mitigation measures. Furthermore, if the ESS developer is not amenable to those requirements, then an express circuit will be required.

Finally, an express circuit may not always resolve issues identified in an interconnection study, especially in cases where voltage regulation is achieved at the substation bus level with a transformer Load Tap Changer (LTC). In such cases, an ESS project may be subject to additional requirements or limitations including charging restrictions, ramp rate control, etc.

2.2.7.1 Example of ESS's export to the grid capability study

An ESS DER will need to charge from the grid and export to the grid. As such, Dominion Energy studies several ramp rate scenarios to quantify the effect of ramping on its grid. Specifically, Dominion Energy studies the export site with the following ramp rates to determine their impact on the system:

Ramp Rate Example

200%	From Full (100%) Charging (full load) mode to Full (100%) Exporting
150%	50% Charging mode to 100% Export
100%	0% Charging mode to 100% Export
50%	0% Export to 50% Export
40%	0% Export to 40% Export
20%	0% Export to 20% Export
-20%	100% Export to 80% Export
-40%	100% Export to 60% Export
-50%	100% Export to 50% Export
-100%	100% Export to 0% Export
-150%	100% Export to 50% Charging
-200%	100% Export to 100% Charging

If any of these violate the 3% voltage dip/rise criteria, the ramp rate will be required to be set such that all voltage violations are mitigated. If all of the studied scenarios violate the 3% delta change in voltage, then simulations will be made with an "express circuit" and the above-mentioned ramp rates will be restudied.

2.3 Transformer Loading Limit requirements

Reverse flow on a substation transformer, defined as power flow from the distribution grid up to the transmission grid, will be limited to the base rate or Oil Natural Air Natural (ONAN) rating of the transformer. When evaluating the maximum aggregated DER on a distribution transformer, Dominion Energy recognizes there is normal load on the distribution transformer and considers a light load factor in addition to the ONAN rating of the transformer. The light load factor is defined as either the actual transformer light load, which is limited to daytime light load for PV only DER systems, or 10% of the transformer top nameplate rating, whichever is the smallest. Given the transfer capacity and switch-ability of the radial distribution system, normal transformer load may be abnormally arranged; this drives the 10% of transformer maximum amount for the light load factor. Ultimately, the maximum aggregate generation connected on a substation transformer will be limited to the summation of the transformer base rating and a light load factor, if any. This also ensures the maximum number of DER sites can be safely connected the circuit. Table 1 provides guidelines for a typical distribution transformer maximum allowable reverse flow and total allowable aggregate DER with respect to the transformer nameplate rating, assuming a light load factor of 10% of the top transformer rating.

Transformer Nameplate Rating (MVA)	Maximum Reverse Flow ONAN (MVA)	Maximum Allowed Aggregate DER ONAN + LLF** (MVA)
6.5 *	3.9	4.6
6.5/7*	4.2	4.9
6/8/10	6.0	7.0
7.2/9.3/12	7.2	8.4
8.4/10.2/14	8.4	9.8
12/16/20	12.0	14.0
13.4/17.9/22.4	13.4	15.7
20.1/26.8/33.6	20.2	23.5
24/40	24.0	28.0
27/ 36/45	27.0	31.5
30/40/50	30.0	35.0
33.6/44.8/56	33.6	39.2
45/60/75	45.0	52.5
50.4/67/ 84	50.4	58.8

* Reverse Flow Rating for non-standard transformer is the lower of the ONAN rating or the base impeadance test rating.

** LLF = Light load factor and is assumed, for reference purpose, to be equal to 10% of the top nameplate rating of the transformer .

Highlighted - Standard Purchase Size

***Table 1* : Transformer Chart - DER Limits**

2.4 Circuit Loading Limit requirements

Dominion Energy has developed circuit loading limit criterion corresponding to the rating of largest conductors used in its system. The circuit loading requirements are described in sections 2.5.1 and 2.5.2 below.

2.4.1 Thermal Limit/ Physical Circuit Capacity

Dominion Energy standard 477 AAC wire size has a maximum rating of 644 Amps. However, given the limitation of other components such as disconnects and bushings, Dominion Energy established the standard circuit maximum ampere rating of 600 Amps. Table 2 below provides guidance on some typical circuit thermal limits, which have different megawatt (MW) equivalents depending on the distribution circuit operating voltage.

	12.5 kV	13.2 kV	23 kV	34.5 kV
MW	Amps	Amps	Amps	Amps
1	46	44	25	17
2	92	87	50	33
3	139	131	75	50
4	185	175	100	67
5	231	219	126	84
6	277	262	151	100
7	323	306	176	117
10	462	437	251	167
12	554	525	301	201
13	600	569	326	218
13.7		600	344	230
15			377	251
20			502	335
24			600	400
28				469
30				502
32				536
36				600

Table 2 : Amps per circuit voltage and equivalent MW

2.4.2 Aggregate DER capacity / limits for intermittent DER

Even though the typical circuit thermal rating may be 600 amps, Dominion Energy has established general guidelines based on the rated voltage for the generation size that corresponds to the circuit amperage that can minimize voltage fluctuation of an associated circuit due to DER. The guideline on generation sizes is shown in Table 3 below. As the distribution system configuration is constantly changing, the limits outlined in the table may be subject to changes at Dominion Energy's discretion.

2.4.2.1 Guidance on aggregate DER limits for intermittent DER

When determining the aggregate DER capacity of an associated circuit, one important component is the circuit loading limit. Other factors that affect aggregate DER limits include the size of conductors within the circuit, the rating of the distribution transformer, and the LTC rating. Table 3 below provides guidance on typical aggregate DER limits that a distribution circuit can accommodate, based on the rated voltage, when interconnecting intermittent DER such as solar PV. The DER limits in Table 3 represent DER sizes that are more likely to incur the least cost of interconnection at the respective voltage levels. Please note that these limits are for informational purpose only and may be subject to changes once other conditions or limitations are factored in during the feasibility and/or system impact study phase(s).

Note: Dominion Energy's experience is that the MW threshold identified in Table 3 will minimize the cost of interconnection. This is not to be confused with Table 2 in section 2.5.1 which articulates conductor ampacity ratings at various voltage levels assuming 477 AAC was installed in the circuit. Details on true limitations of the circuit and needs for upgrades will be documented in the interconnection study.

	12.5 kV	13.2 kV	23 kV	34.5 kV
	MW	MW	MW	MW
Aggregate DER	6.0	7.0	12	24

***Table 3*: Typical Aggregate DER Limit (MW) – per circuit voltage**

For the unique case of ESS DER, Table 3 can be considered a limit on the aggregate amount of ESS capacity that can be connected to a distribution circuit for each voltage level. This is due to the unique export and import (charging) capability of ESS. More generally, there is a strict 24 MW import limit for any ESS connecting to Dominion Energy's distribution system (which correlates to 400 amps at 34.5 kV, or about 2/3 the maximum capacity of the equipment on the circuit). Any proposed ESS project that will import more than 24 MW will need to connect at transmission voltage levels (69 kV and above) and should be processed through the PJM queue. This limit is in place to ensure the reliability and operational flexibility of the EPS is maintained. ESS projects generally do not adjust power output as intermittently as other forms of DER and instead, when in charging mode, will absorb a constant amount of power from the grid.

2.4.3 Aggregate DER capacity / Limits for non-intermittent DER

A non-intermittent DER (e.g. hydroelectric, biomass, landfill gas, etc.) is defined as a DER that is not variable in nature, as it is not dependent on environmental or external conditions such as level of irradiance, wind speed, etc. Non-intermittent DER typically do not affect circuit voltage regulation like an intermittent DER does. Given such characteristics, the limits in Table 3 above may be exceeded for a non-intermittent DER, subject to the review and approval of Dominion Energy. This will ensure power quality and electric distribution equipment limitations are not violated.

2.5 Grid Support Capability

Dominion Energy defines grid support as DER equipment capabilities and functionalities required by IEEE Std. 1547-2018 for purposes of maintaining reliable operation of the EPS and responding to the variability of electric power supply and demand. These capabilities include real and reactive power support. Dominion Energy is continuing to evaluate the multitude of control modes available to IEEE 1547-2018 certified inverters and their impact on the safety and reliability of the EPS.

2.5.1 Grid Support Capability Requirements

Dominion Energy acknowledges the capability of most DER to provide grid support within their design specification(s) and limitation(s). Although inverter-based DER may be capable of providing a higher level of grid support using smart inverter functionalities, Dominion Energy is responsible/liable for ensuring that EPS voltage remains within the ranges allowed by the respective state jurisdiction. Accordingly, Dominion Energy designs its EPS without creating a dependency on DER grid support functions for normal day to day operations of the EPS for reliability purposes, so that the safety and reliability of the EPS is not ceded to a third party. Dominion Energy has established the following standard to ensure that result: DER interconnection related upgrade(s) or infrastructure solutions shall initially be established to mitigate any voltage, thermal, power quality, and other safety related issues, at the DER developer's expense, caused by the addition of the proposed DER before any DER is requested to provide grid support functionalities. Dominion Energy may use those grid support functionalities for future operational issues, including but not limited to adverse operating conditions, after all infrastructure solutions and associated mitigation tools have been exhausted. Limited exceptions may be made when utilizing some smart inverter functions such as power factor adjustment, ramp rate control, a watt-var curve, and/or a volt-var curve. Section 2.8 below provides a non-exhaustive list of mitigation measures for voltage, thermal, power quality, and other reliability violations.

2.6 Ride-through Capability Requirements

Although Dominion Energy supports the IEEE 1547-2018 ride-through capability requirements for DER, Dominion Energy is not requiring the application or utilization of ride-through functionalities at this time. Table 4 below outlines current Dominion Energy requirements associated with DER Voltage ride-through. Please note any requirements within the table may be subject to change at Dominion Energy's discretion.

Voltage Range (p.u.)	Operating Mode	Clearing time (s)
1.20 – 1.10	Momentary Cessation	2

1.10 – 0.88	Continuous Operation	∞
0.88 – 0.50	Mandatory Operation	2
0.50 – 0.00	Momentary Cessation	0.16

Table 4: Dominion Energy Voltage Ride-Through Requirements
(Source: IEEE Std. 1547a-2020, Category III)

2.7 Equipment Reviews

As part of the interconnection study for DER, Dominion Energy will assess the loading limit associated with interconnecting the requested generator. If Dominion Energy determines that any of the limits described in previous sections (i.e. sections 2.4, 2.5.1, and 2.5.2) are exceeded, the following upgrade requirements may apply prior to the interconnection of the DER. Those requirements include but are not limited to:

- Conductor upgrade
- Transformer upgrade to the next standard size up that will accommodate the DER addition
- Substation regulator and/or associated control upgrade
- Line regulator and/or associated control upgrade
- Addition of new express feeder
- Addition and/or upgrade of line recloser(s)
- Circuit and/or Transformer rearrangements considered good utility practice
- Protection and coordination reviews
- Other equipment upgrades due to fault duty

3 DER General Interconnection Parameters

Dominion Energy has two typical DER connections depending on the size of the DER. These typical connections are DER less than 1 MW in size and DER of size 1 MW and above. The connections and typical equipment installation configurations are discussed in sections 3.2 and 3.3 below and are applicable to all DER technologies. Appendix A provides additional information on the typical layout of associated DER interconnection or attachment facilities. Please note, in terms of distribution system voltage applicable to a DER Interconnection, it is Dominion Energy's policy that all DER will connect at the distribution substation bus voltage.

As an example, to explain this policy, consider a DER whose attachment facilities are located downline from a distribution circuit's step-down transformer. The step-down transformer drops substation potential down to a lower potential prior to arriving at the DER attachment facilities. Dominion Energy's current policy for such interconnections is to remove the step-down transformer and interconnect the entire circuit at the substation potential. In limited cases, it may be possible to instead install a step-up transformer near the proposed DER to operate the DER at the distribution substation bus voltage and avoid a portion of voltage conversion. This determination will be made on a case-by-case basis in the feasibility study phase.

3.1 DER Interconnection Generator Step-up Transformer Requirements

The following generator step-up (GSU) transformer requirements apply to all DER paralleling with the Dominion Energy EPS regardless of their applicable interconnection parameters. Any Dominion Energy supplied GSU transformer for use with the interconnection of a DER will have a Wye-grounded / Wye-grounded winding configuration. If a DER developer elects to have Dominion Energy supply the GSU transformer, steps must be taken to ensure that the DER protection system associated with inverters handles that type of configuration. For any GSU transformer supplied by the DER developer, Dominion Energy will require a GSU that has either a Wye-ground / Wye-ground or Wye-ground/Wye (DER Side) winding configuration.

3.2 Interconnection Parameters for DER < 1 MW (Low Voltage Metering)

For an interconnection of a DER less than 1 MW connecting at the low voltage side of a Dominion Energy-owned distribution transformer (i.e., typically 277/480 volt), a low voltage, shunt trip breaker and a Power Quality (PQ) device will be required prior to the interconnection. The PQ device will provide the Dominion Energy Regional Operation Center (ROC) real time status of the generation through constant polling as well as control capability of the low voltage breaker. Details on the possible interconnection parameters for DER < 1 MW are provided in Figure 1 below.

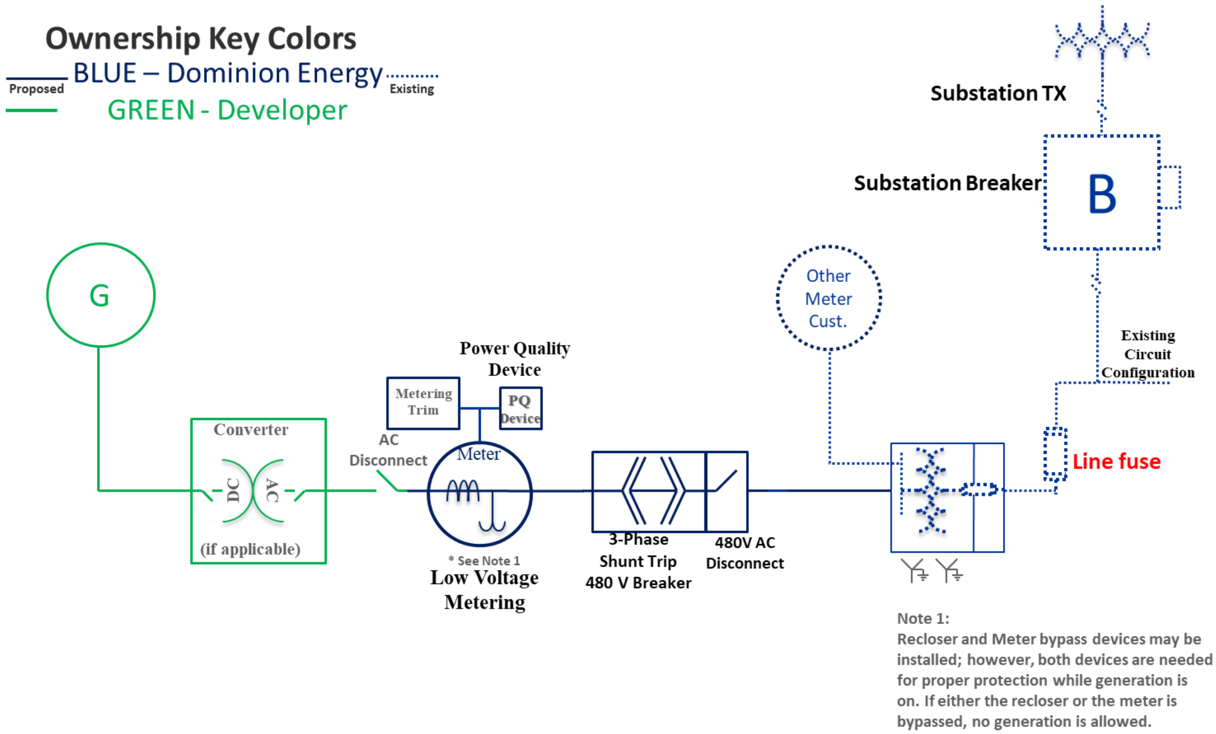


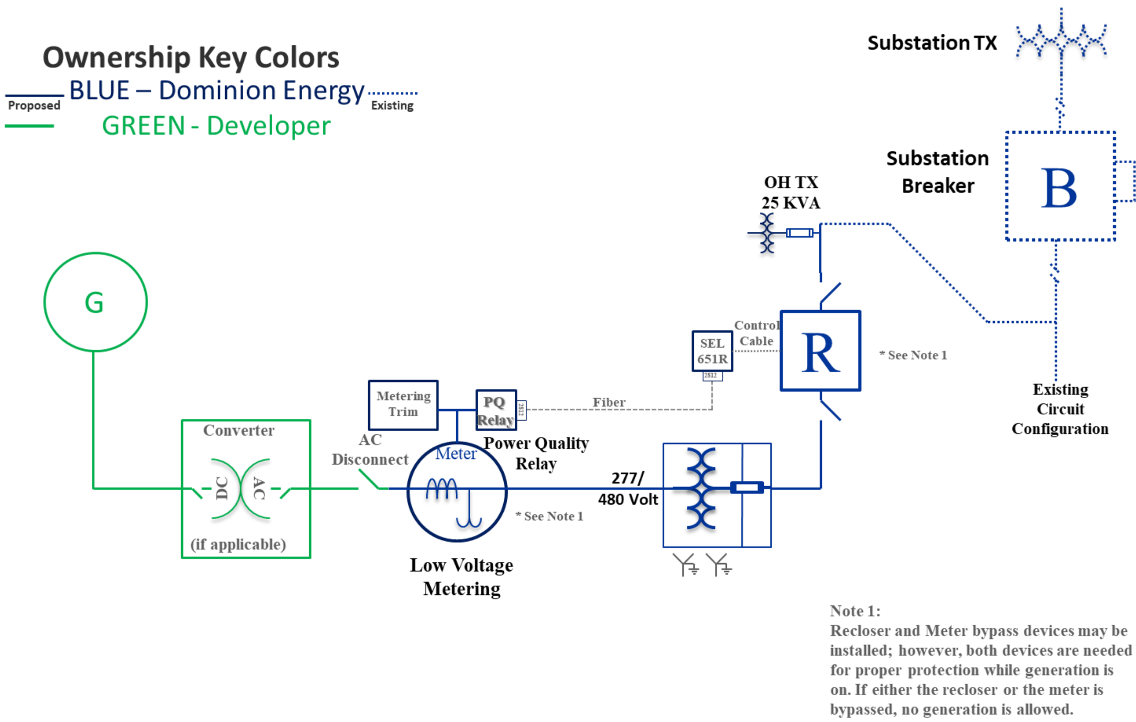
__Figure 1__: Typical Layout for DER Gen < 1 MW

3.3 Interconnection Parameters for DER ≥1 MW

The following subsections describe 3 different interconnection configurations for DER 1 MW and above.

3.3.1 DER ⩾1 MW (DER behind Dominion Energy's overhead transformer, low voltage metering)

For an interconnection of a DER above 1 MW consisting of a single DER or a single IEEE 1547 certified inverter connecting at the low voltage side of a Dominion Energy owned transformer off an overhead line, a recloser with a SEL-651R controller will be required at the medium voltage side of the transformer (i.e., typically 34.5 kV). Also, a PQ device will be required at the low voltage side prior to interconnection. The typical winding configuration of a Dominion Energy owned distribution transformer will be Wye-ground / Wye-ground. The developer has the option of having the attachment facilities installed either overhead or underground. It should be noted that underground attachment facilities incur a higher cost than overhead. Further details on the interconnection parameters for DER > 1 MW consisting of a single inverter for overhead attachment facilities are provided in Figure 2 below**.** Further details on the interconnection parameters for DER > 1 MW on overhead facilities consisting of a single inverter for underground attachment facilities are provided in Figure 3 below**.**



<u>Figure 2</u>: Typical Layout for DER ≥ 1 MW (Dominion Energy owned overhead Transformer)

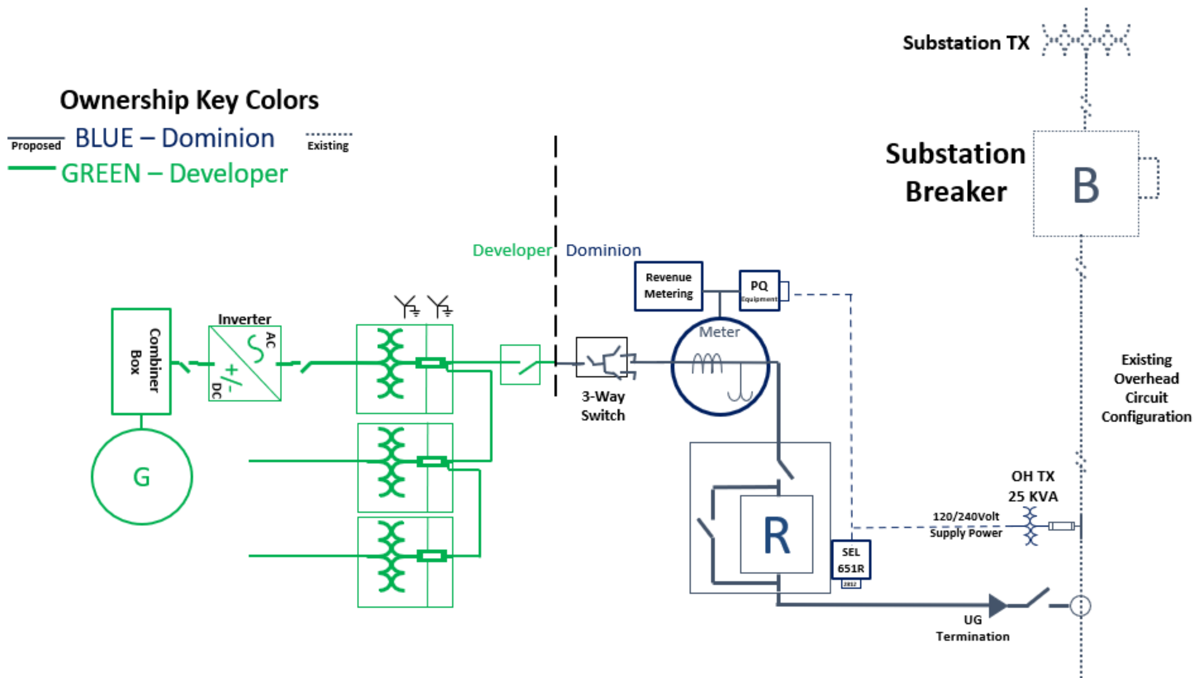
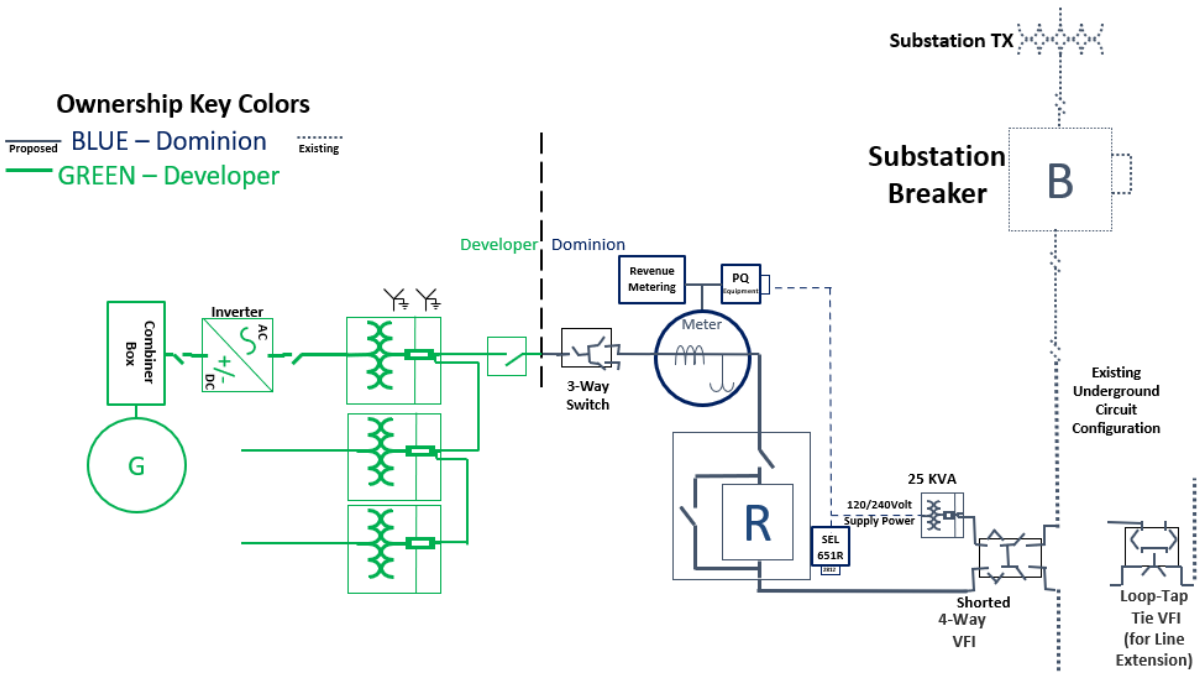


***Figure 3**: Typical Layout for DER ≥ 1 MW (Developer owned Transformer with underground attachment facilities from an existing overhead line)*

3.3.2 DER ⩾1 MW (DER behind Dominion Energy's underground transformer, low voltage metering)

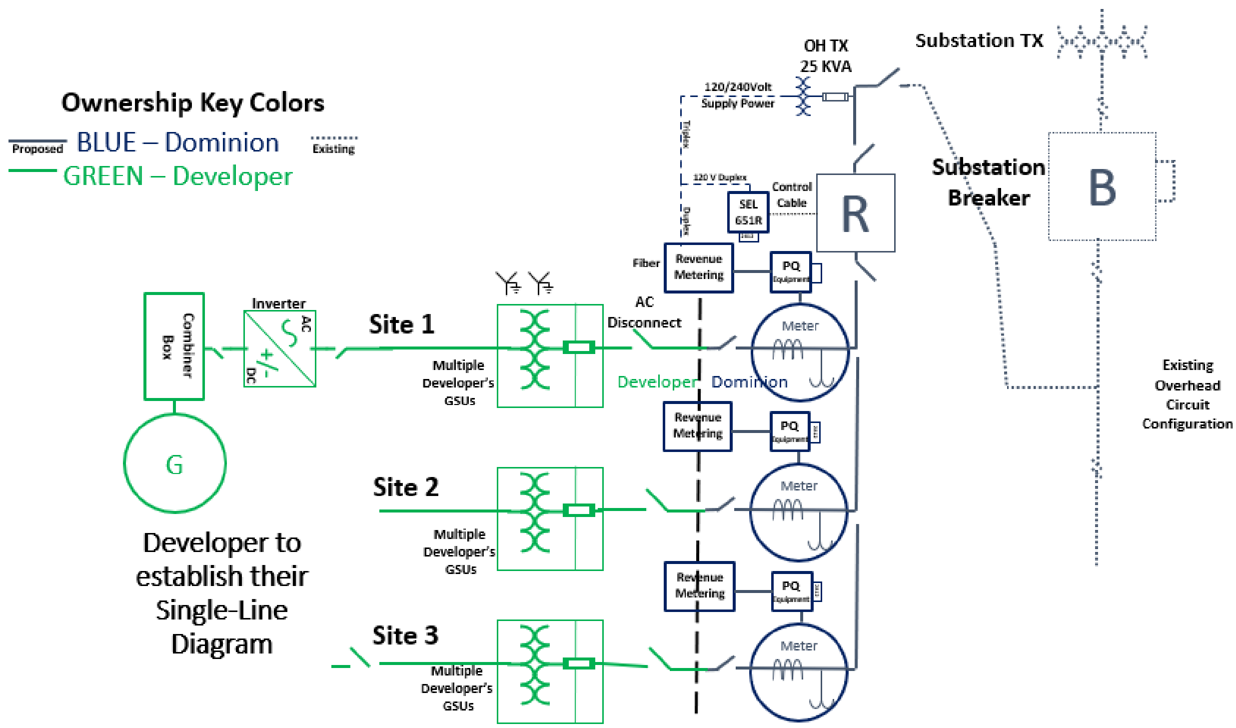
For an interconnection of a DER above 1 MW consisting of a single DER or a single IEEE 1547 certified inverter connecting at the low voltage side of a Dominion Energy owned transformer off an underground line, a padmount recloser with a SEL-651R controller will be required at the medium voltage side of the transformer (i.e., typically 34.5 kV). Also, a PQ device will be required at the low voltage side prior to interconnection. The typical winding configuration of a Dominion Energy owned distribution transformer will be Wye-ground / Wye-ground. A developer owned distribution transformer must be either Wye-ground / Wye (DER side) or Wye-ground / Wye-ground. Further details on the underground interconnection parameters for DER > 1 MW connecting to an existing underground line consisting of a single inverter are provided in Figure 4 below.



<u>Figure 4</u>: Typical Layout for DER ≥ 1 MW (Developer owned Transformer with underground attachment facilities from an existing underground line)

3.3.3 DER ≥ 1 MW (DER developer-owned transformer, multiple metering points)

For interconnection of DER above 1 MW consisting of multiple DER or multiple inverters connecting at the medium voltage side, a recloser with a SEL-651R controller and a PQ device will be required prior to interconnection. The PQ device will provide the Dominion Energy ROC real time status of the generation through constant polling as well as control capability of the POI recloser. The typical winding configuration of the GSU transformer allowed by Dominion Energy will be Wye-grounded / Wye (DER side) or Wye-grounded / Wye-grounded. There are different configurations for this setup for an overhead line connecting to overhead attachment facilities, an overhead line connecting to underground attachment facilities, and an underground line connecting to underground attachment facilities. Further details on the interconnection parameters for DER ≥ 1 MW consisting of multiple inverters for all three configurations are provided in Figures 5, 6, and 7 below.



<u>Figure 5:</u> Typical Layout for DER ≥ 1 MW (DER developer-owned Transformer for overhead attachment facilities from an overhead line) with multiple sites/metering points

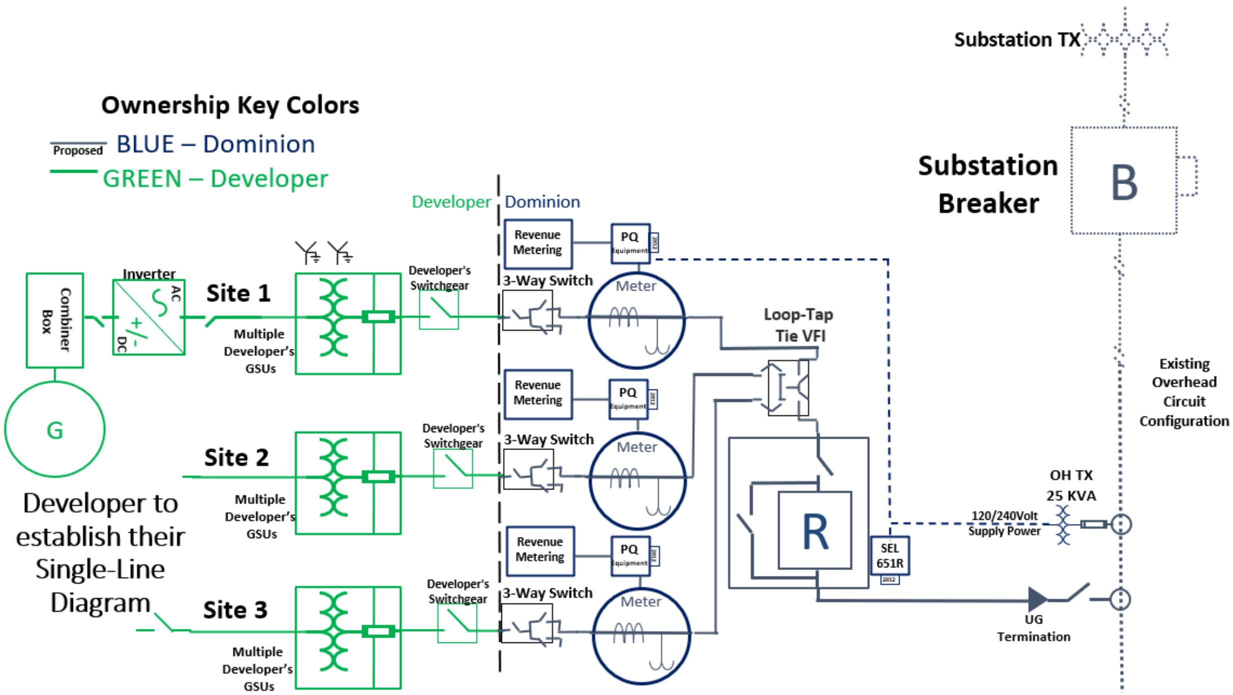


Figure 6: ***Typical Layout for DER ≥ 1 MW (DER developer-owned Transformer for underground attachment facilities from an overhead line) with multiple sites/metering points***

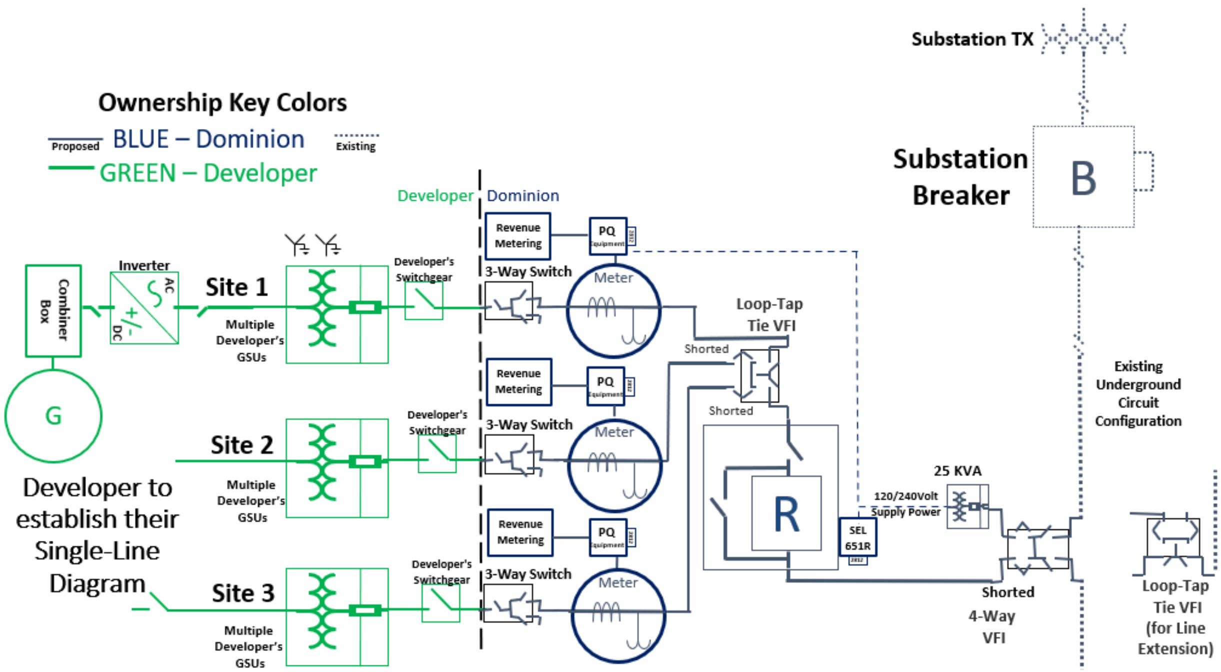
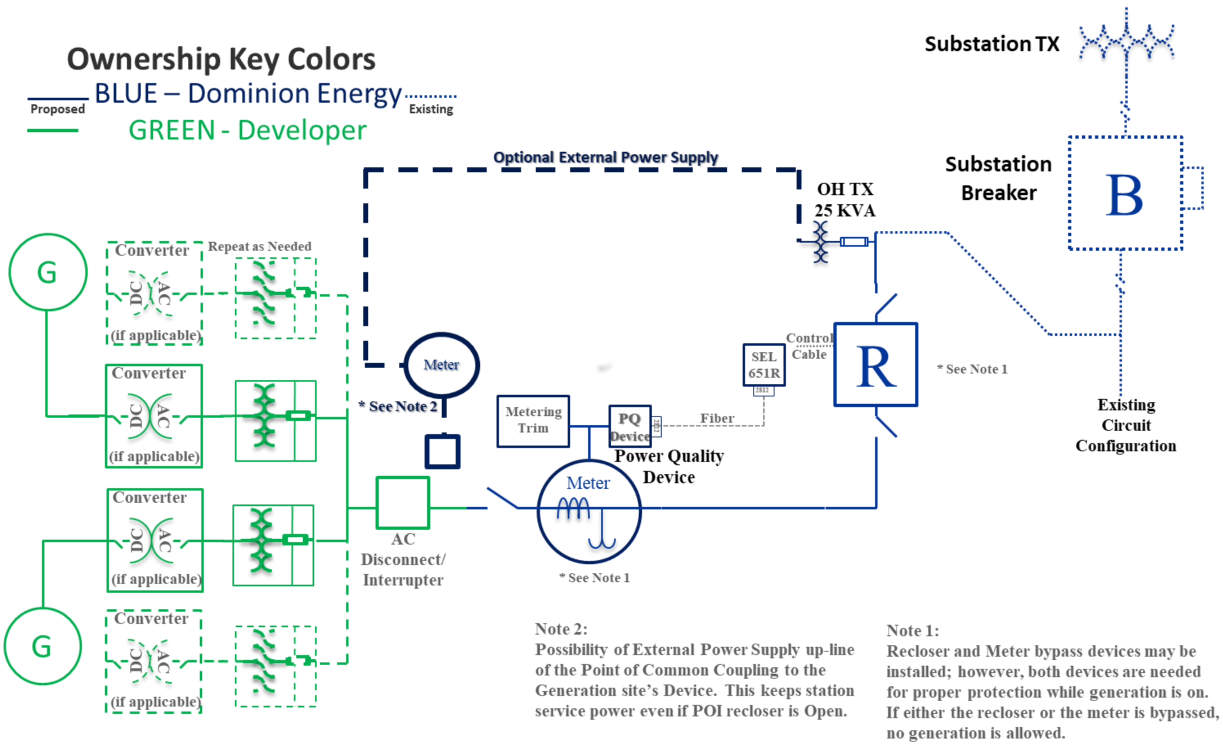


***Figure 7:* Typical Layout for DER ≥ 1 MW (DER developer-owned Transformer for underground attachment facilities from an underground line) with multiple sites/metering points**

3.3.4 External power supply for DER ⩾ 1 MW (DER developer-owned transformer)

A DER site typically requires site power. Many Developers choose to pull this site-service power from their own electrical bus. If the site requires protection transfer trip, this site service power will be interrupted with the opening of the transfer trip target device – the POI recloser. For the interconnection of a DER above 1 MW consisting of multiple DERs or multiple inverters connecting at the medium voltage side, the DER developer has the option of obtaining an additional external power supply up-line from the POI to the DER site for service power needs. This could be an alternate power supply to the site for emergency/auxiliary load. Further details on the parameters of the external power supply are provided in Figure 8 below.



<u>Figure 8</u>: External Power Supply for DER ≥ 1 MW (DER developer-owned Transformer)

4 Wind Turbine Systems Interconnection Study Parameters

Wind Turbine Generation (WTG) is a type of generation technology that brings some additional challenges that are not addressed in a typical interconnection study as described in Section 2. This section describes how such challenges are addressed by providing additional guidance concerning the interconnection study requirements.

4.1 Voltage Stability

4.1.1 Voltage stability study process

As discussed in section 2.2, Dominion Energy performs voltage studies on all proposed DER sites as well as power flow studies. Dominion Energy also performs voltage studies for WTGs that propose to interconnect.

In addition to voltage studies, Type I & II WTGs will require an inrush current study to evaluate start-up voltage dip that results from inrush current. If a soft start unit is used on a Type I or II WTG, the current that the soft start unit limits will be used for this study. The developer will need to provide the noted current limit as part of the study agreement.

4.1.2 Voltage fluctuation mitigation

If the voltage study reveals power quality issues such as RVC or flicker, Dominion Energy will apply current mitigation practices used for other DER to WTG interconnections. Techniques for mitigation are discussed in section 2 (DER General Study Parameters). Furthermore, during the study process, if voltage dip upon WTG start up is shown to be an issue, the developer will need to implement a mitigation solution. The solution may include, but is not limited to, the installation of a soft starter to minimize the effect of machine starting.

4.2 Generator Step-up Transformer Configuration

Section 3.1 states that Dominion Energy requires a Wye-ground / Wye-ground or Wye-ground / Wye (DER Side) GSU winding configuration. With WTG, Dominion Energy recognizes that it is common for manufacturers to require Delta / Wye-ground winding connections. However, such winding configuration if utilized can lead to overvoltage during ground faults, the desensitization of ground protection devices, and protection coordination issues.

At Dominion Energy's discretion, a WTG requiring a delta winding configuration on the utility side may be authorized to interconnect with the appropriate DTT scheme installed. In addition, more sensitive settings may be needed on the POI recloser to protect the distribution system.

4.3 Harmonics Review and Mitigation

Section 2.2.3 provides guidance on the harmonics study process and mitigations that also apply to WTGs interconnection. Refer to these sections for guidance.

4.4 Reactive Power Support

4.4.1 Reactive power study process

As discussed in section 2.2, all proposed DER interconnections are currently studied with at a fixed power factor, typically unity (1.0 PF). The same requirement applies to any WTGs.

4.4.2 Reactive power mitigation

To mitigate the lack of reactive power control in Type I & II WTGs, a D-STATCOM or similar reactive power control device may be required for any WTG DER interconnections that are 500 kW and above. Type III &

IV WTGs are considered inverter-based generation for reactive power control and will typically not be subject to those requirements.

5 Energy Storage System (ESS) Study Parameters

This Section provides interconnection parameters for Energy Storage Systems (ESS) and other inverter-based storage systems that are interconnecting for the primary purpose of exporting energy onto the EPS. This section is largely focused on grid-scale stationary/mobile storage systems, ESS in a microgrid, ESS onboard of Electric Vehicles (EV), and Vehicle-to-Grid (V2G) functionality.

An ESS is a particular type of DER that has the ability not only to store energy from the EPS but also to inject its stored energy onto the EPS. This makes ESS both a load and a generation source. Thus, there is a need for a different approach when studying an interconnecting ESS. ESS interconnection requirements are based not only on Good Utility Practice but also on operating experience, which has proven that energy storage can cause the same issues associated with the intermittency of the renewable energy (RE) resources if the energy storage is not optimally operated. The study/review is accomplished through the following steps: (i) technology review, (ii) review of the proposed application and operating modes, (iii) identification of the interconnection configuration, and (iv) analysis of the ESS study parameters for each proposed application. Regardless of the ESS applications and configurations, the DER interconnection requirements will apply when the ESS serves as a generator and exporting power to the grid. Load restrictions will apply when the ESS serves as a load and imports power from the grid. When the ESS serves both as a generator and a load, DER interconnection requirements and load restrictions shall apply. Figure 9 shows the flowchart of ESS interconnection review procedure.

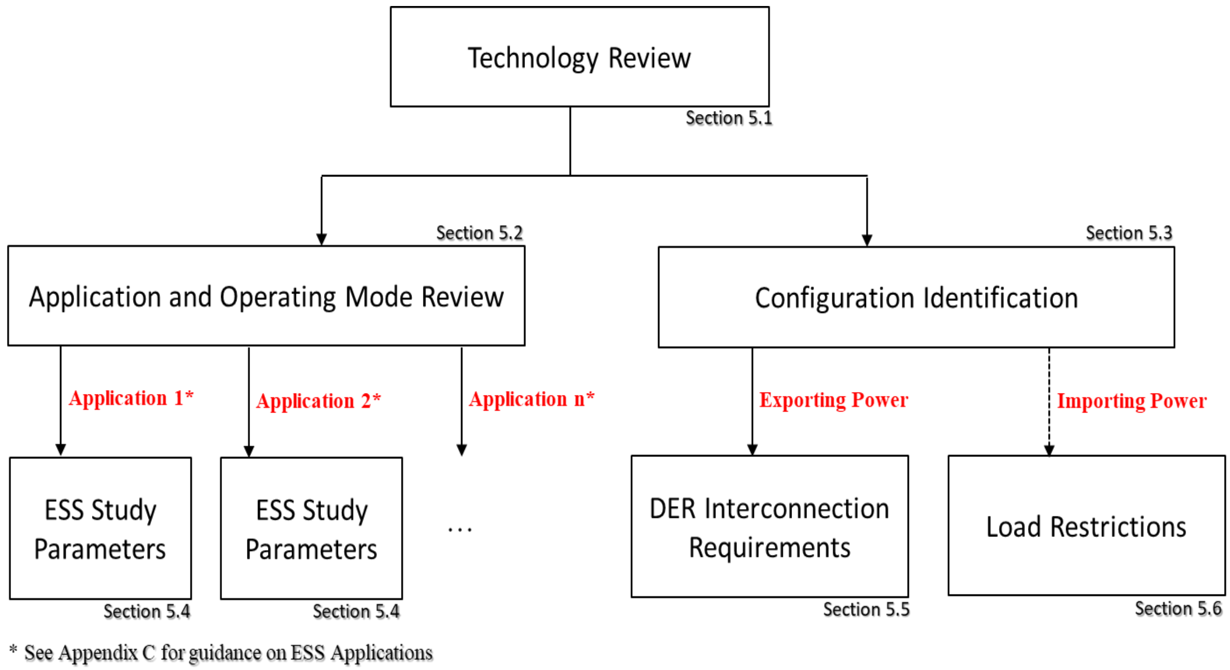


***Figure 9*: ESS interconnection review procedure flowchart**

As detailed in section 2.4.2.1, there is a strict 24 MW charging limit on the 34.5 kV system (which corresponds to 400 A), or about 2/3 the maximum capacity of the equipment on the circuit, for ESS connecting to the distribution system. Any ESS projects above 24 MW will need to connect at transmission voltage levels (69 kV and above). This limit follows Good Utility Practice to ensure the reliability and operational flexibility of the EPS is maintained. ESS projects generally do not adjust power output as intermittently as other forms of DER and instead, when in charging mode, will absorb a constant amount of power from the grid.

As an additional note, large requested ramp rates for large amounts of energy may also cause unacceptable changes in voltage to the distribution system. Instantaneous changes from full charging to full discharging for large ESS projects may not be possible without causing operating violations. A typical BESS project connecting at distribution voltage will require a watt-var curve to allow full charging and discharging without negatively impacting the system voltage. Normal watt-var curves will result in a power factor within+/-0.95 absorbing/producing reactive power (VARs) when discharging or producing active power (MWs).

Furthermore, since ESS projects operate as both a load and a source due to their charging and discharging capabililty, following Good Utility Practice there will need to be a set amount of capacity on the substation distribution transformer reserved to ensure the reliability and operational flexibility of the EPS is maintained. Like any loading project on the Utility's system, it is important to ensure that any addition of load does not jeopardize existing plans designed to maintain customer service during any abnormal condition on the distribution system. This may require restrictions to be imposed on the operation of the ESS that will be outlined in the feasibility study results for each ESS project. Technology Review

ESS includes any system that contains a power conversion system, storage modules (e.g., battery packs) and storage management system (if applicable), controller, thermal management system and monitoring devices that can import energy from and export energy to the grid. In the case of the battery energy storage system (BESS), the system is composed of various types of electrochemical cells. Energy can be stored in the BESS and dispatched through a reversible electrochemical reaction.

Based on the forms of the ESS outlined above, the following four applications of ESS are currently acknowledged and accepted for the interconnection study.

- Stationary ESS
- Mobile or transportable ESS
- ESS in a microgrid
- ESS on-board Electric Vehicles (EV) with Vehicle-to-Grid (V2G) functionality

Technology reviews will be completed by Dominion Energy based on the ESS technology applications and the DER General Study Parameters identified in section 2 of this Guide. Any technology and parameters outside of the scope of this document will be handled in a separate review.

5.1 Application and Operating Modes Review

An ESS is interconnected to the EPS to store energy and release it at a later time. Based on the charging/discharging conditions, time schedule, and operational objectives, there are 5 major categories and 17 grid support applications concerning an ESS. These applications are shown below in Table 5. Detailed descriptions of these 17 applications are shown in the Appendix B.

Table 5*: General ESS Applications*

Category	**No.**	**Application**
Electric Supply	1	Electric energy time shift
	2	Electric supply capacity
Ancillary Services	3	Electric supply reserve capacity
	4	Load following

	5	Frequency regulation
	6	Voltage support
	7	Blackstart
T&D Grid Services	8	Transmission congestion relief
	9	Transmission and Distribution (T&D) upgrade deferral
	10	Transmission and Distribution (T&D) support
Customer Management Services	11	Time of Use (TOU) energy cost management
	12	Demand charge management
	13	Electric Vehicle (EV) charging integration
	14	Electric service reliability
	15	Electric service power quality
Renewable Integration	16	Renewable energy time shift
	17	Renewable capacity firming

Dominion Energy will review and study all individual applications that are identified in the interconnection request. If multiple applications are proposed, all applications should be clearly identified in the interconnection request. Failure to include all applications and operating modes in the interconnection request may lead to delay in processing the interconnection request, removal from the queue, and/or restriction of possible uses.

5.2 Configuration Identification

The term "coupled" defines how an ESS is connected to a DER. This is done using either the DC side or AC side of the ESS. The ESS in general can be designed to couple in the following three categories:

1: AC coupled ESS: ESS is connected directly to the utility's AC grid. It is a standalone system with no other source than the utility.

2: AC-coupled ESS with DER: ESS is coupled with a DER source at the AC side and connected to the utility grid.

3: DC-coupled ESS: ESS is coupled with a DER at the DC side.

Under categories 1 and 2, there are three configurations defined for the ESS functionality.

A: Inverter with grid forming capability.

B: Inverter with grid following capability.

C: Inverter with both grid forming and grid following capability.

General ESS interconnection configurations are summarized in Table 6. The ESS developer should provide a detailed construction configuration description following the format of Table 6 and one-line diagrams to Dominion Energy as part of the interconnection request. This information will aid in identification of the proper system configuration and appropriate infrastructure upgrades needed.

Detailed descriptions of each configuration are discussed in Appendix C.

Table 6: General ESS Interconnection Configuration

	AC connected ESS			AC coupled ESS			DC coupled ESS
Configuration	1A	1B	1C	2A	2B	2C	3
	Standby ESS	ESS for Grid following	ESS for Grid forming and following	Standby ESS in a RE site	ESS paired with RE generation	ESS for a microgrid	ESS 100% charged by RE generation
Application	14	1-13,15	1-15	14	1-13,15-17	1-17	16-17
Directional Inverter	Bi-directional	Bi-directional	Bi-directional	Bi-directional	Bi-directional	Bi-directional	Uni-directional
Grid-forming?	Yes	No	Yes	Yes	No	Yes	Hybrid, uni-directional inverter
Grid-following?	No	Yes	Yes	No	Yes	Yes	Yes
Paired with RE?	No	No	No	Yes	Yes	Yes	Yes
Interconnection Review Required?	No*	Yes	Yes	No*	Yes	Yes	Yes
Storage Charging	Utility or self-generation	Utility	Utility	Utility or RE generation	Utility or RE generation	Utility or RE generation	100% RE generation
Storage Discharging	Critical load only	Export	Export	Critical load only	Export	Export/ Islanding	Export

*An Interconnection Agreement is not required if standby ESS source cannot be used to generate power while connected with the utility (e.g., open transitions only), or if closed transitions can be proven through documentation and testing to parallel with the utility for <100ms and provide necessary backup protection approved by the utility.

5.3 ESS Study Parameter Review

All ESS project developers are required to provide a set of relevant ESS study parameters as listed below. These parameters should be provided for each proposed ESS application as referenced in Table 5 (General ESS Applications). For any value stacking considerations, a set of parameters should be provided for each application and operating mode.

5.3.1 Point of Interconnection Identification

The POI should be provided, and the measurement meter should be identified.

5.3.2 Power and Energy Ratings

The ESS developer shall provide the apparent power rating of the inverter in MVA and the energy rating in MWh.

5.3.3 Maximum/Minimum MW/MVAR output

For each application, the maximum/minimum active and reactive power output at the POI will need to be provided. The output may be equal or less than the apparent power rating. If active power and reactive power can be dispatched in conjunction, the priority control mode should be listed.

5.3.4 Charging and Discharging Limits

Unlike solar (PV) generators, which only generate power during day light hours, an ESS can generatepower at any time and can charge at any time. To accurately capture this behavior, an 8760 analysis is performed for all ESS projects. An 8760 analysis is a year's worth of an hour-by-hour analysis or study of the load and/or other criteria or associated profile consisting of (24hrs/day X 365 days =) 8760 hours. The 8760 analysis will determine if thermal violations exist for the substation distribution transformer during operation of the ESS. Dominion Energy's current policy is to mandate substation distribution transformer replacement if the transformer cannot support the entire requested capacity for charging of the ESS for any duration of the 8760 analysis, regardless of a developer-provided charging limit. However, if a Dominion Energy-provided charging limit can avoid a transformer upgrade, this will be considered on a case-by-case basis. It is important to note that a Dominion Energy-provided reduced charging limit will impact the length of time it takes for the ESS to achieve full charge. For example, if a study reveals a 20 MW / 60 MWh proposed ESS can charge at a rate of 5 MW at any time without overloading the substation transformer, the battery will take (60 MWh / 5 MW =) 12 hours to fully charge instead of (60 MWh / 20 MW =) 3 hours to fully charge if the limit was not present. This trade-off must be carefully considered for operations purposes, even if this limit could avoid the need to upgrade the substation distribution transformer. This reduced charging limit is subject to change with changes in the EPS.

5.3.5 Ramp Rate, Response Time, and Charge/Discharge Limits

Ramp rate, Response Time, and Charge/Discharge Limits are required to be provided.

Any Dominion Energy-provided reduced charging limits will affect the ramp rate of the ESS, which can have operational impacts on the ESS.

Ramp rate is defined as the increase or reduction in output per minute. It is usually expressed as megawatts per minute (MW/min). A positive ramp rate indicates power increase while the negative ramp rate indicates power reduction from the perspective of the distribution system.

Response time is defined as the duration from the time the control condition is met to the time the device is producing at least 90% of its final output according to IEEE Std. 1547-2018.

Charge/Discharge limits are defined as specific limits enforced to limit the energy taken from the utility or discharged to the utility during operation of the ESS.

If there is more than one operating mode, both ramp rate and response time are required to be provided for each operating mode. Additionally, if an ESS is participating in the wholesale market, it will be the responsibility of the ESS developer to enter or request the adequate program/rate structure that would allow the ESS to stay within Dominion Energy requirements with respect to ramp rate and charge/discharge rate limits.

Please note that a developer self-imposed ramp rate and/or charge/discharge limit does not eliminate the need for upgrades when the ESS fails any duration of the 8760 analysis. Dominion Energy's Policy of requiring a transformer replacement to support the entire requested capacity for charging of the ESS for the duration of the 8760 analysis still applies.

5.3.6 Inverter Specification

The ESS developer shall provide the ESS inverter specifications and certifications. As discussed in section 2.1 of this Guide, any DER equipment paralleling with the EPS (in this case an ESS inverter), regardless of configuration, shall be certified to the UL 1741 standard.

5.3.7 Fault Current Contribution

The ESS developer shall provide the fault current contribution of the ESS.

5.4 Load Restrictions

When the ESS is operating as a load and is importing power from Dominion Energy's EPS, load restrictions (also referred to as charging limits/restrictions) may be applied at the proposed interconnection site. Developers should specify their intention for accepting potential charging restrictions. Depending on the results of the feasibility study, full charging of a large EPS could result in the need for extensive upgrades to mitigate violations. Large loads stress the EPS, especially intermittant large loads. A large EPS at full charge can cause significant thermal and/or voltage violations if no charging limit is enforced. As a result, it is likely large EPS projects will require a charging limit to prevent stress on the EPS.

6 Applicable Guides, Codes & Standards, State Jurisdictional Rules & Procedures

The following list of applicable guides, codes and standards, state jurisdictional rules and procedures is not meant to be exhaustive. Procurement and understanding of standards referenced within this document are the responsibility of interconnection customer.

20 VAC 5-314: Code of Virginia, State Corporation Commission, Chapter 314, Regulation Governing Interconnection of Small Electrical Generators.

Docket No. E-100, Sub 101: North Carolina Utilities Commission, Interconnection Procedures, Forms and Agreements, For State-Jurisdictional Generator Interconnections.

IEEE Std. 1547-2018: IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.

IEEE Std. 1547a-2020: IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.

Amendment 1: To Provide More Flexibility for Adoption of Abnormal Operating Performance Category III.

IEEE Std. 1547.1: IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.

UL 1741: Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources.

UL 6141: Wind Turbines Permitting Entry of Personnel.

UL 6142: Small Wind Turbine Systems.

UL 1973: Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications.

UL 9540: Standard for Energy Storage Systems and Equipment.

IEEE 519-2014: IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.

IEEE P2030.2.1/D7.0: IEEE Draft Guide for Design, Operation, and Maintenance of Battery Energy Storage Systems, both Stationary and Mobile, and Applications Integrated with Electric Power Systems.

IEEE 2032.2-2015: IEEE Guide for the Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure.

ANSI C84.1: Electric Power Systems and Equipment—Voltage Ratings (60 Hz).

IEEE 1453-2015: IEEE Recommended Practice for the Analysis of Fluctuating Installations on Power Systems.

IEEE C62.92.6-2017: IEEE Guide for Application of Neutral Grounding in Electrical Utility Systems, Part VI – System Supplied by Current-Regulated Sources.

IEEE C62.41.2: Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and less) AC Power Circuits.

NFPA 70: National Electric Code (NEC).

NFPA 855: Standard for the Installation of Stationary Energy Storage Systems.

NESC: National Electrical Safety Code.

APPENDIX A:
Typical Layout of Connection Facilities

<u>Figure 1</u>: Typical Primary Distribution Facility Layout

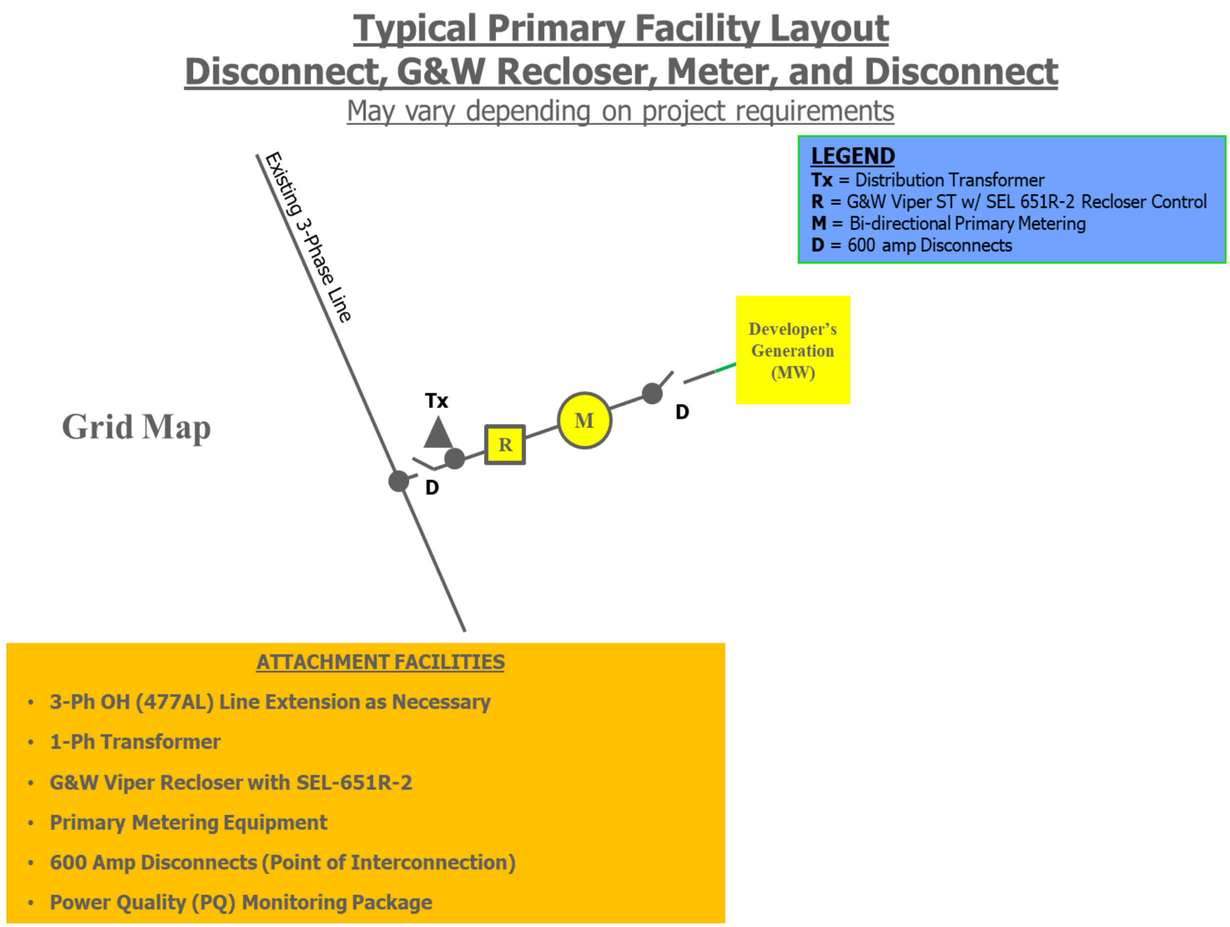


Figure 2: Typical Primary Distribution Facility Layout with additional details (DER developer owned transformer)

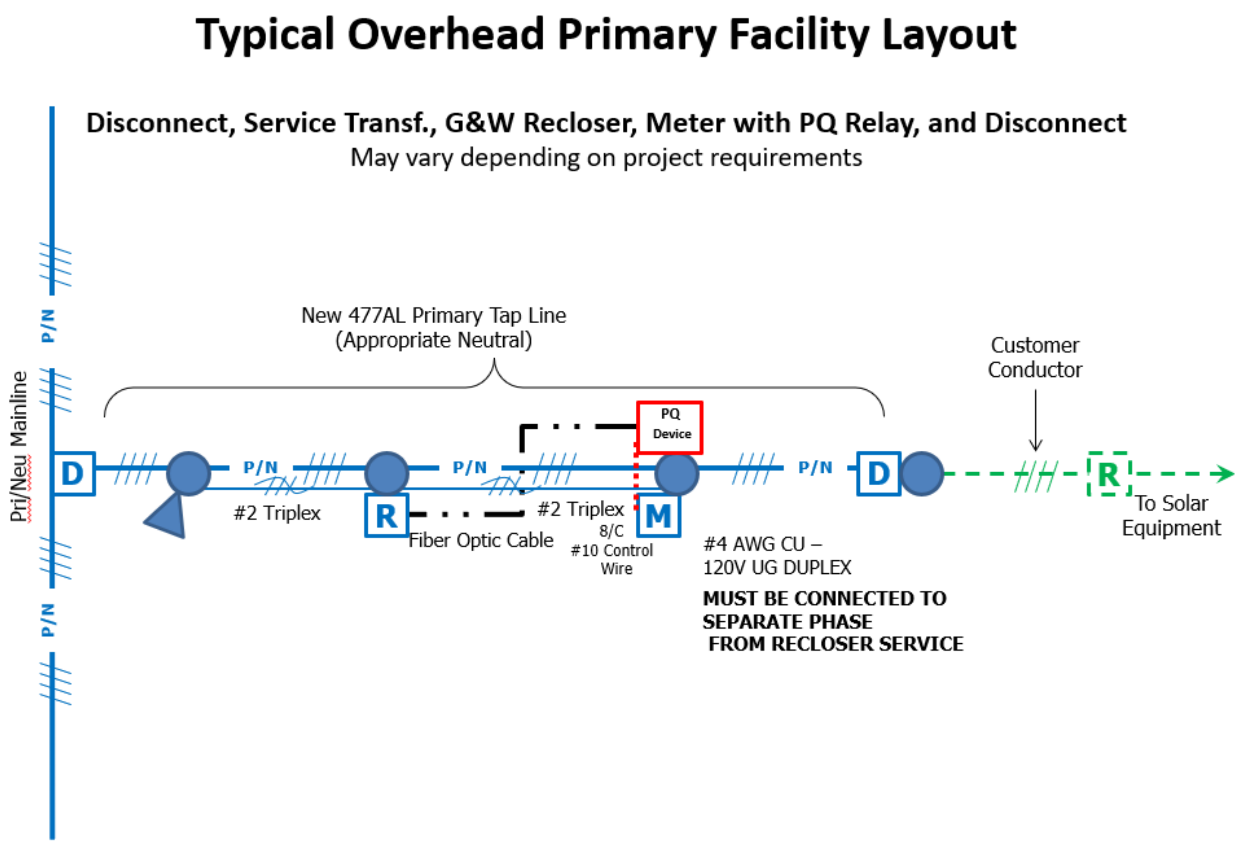
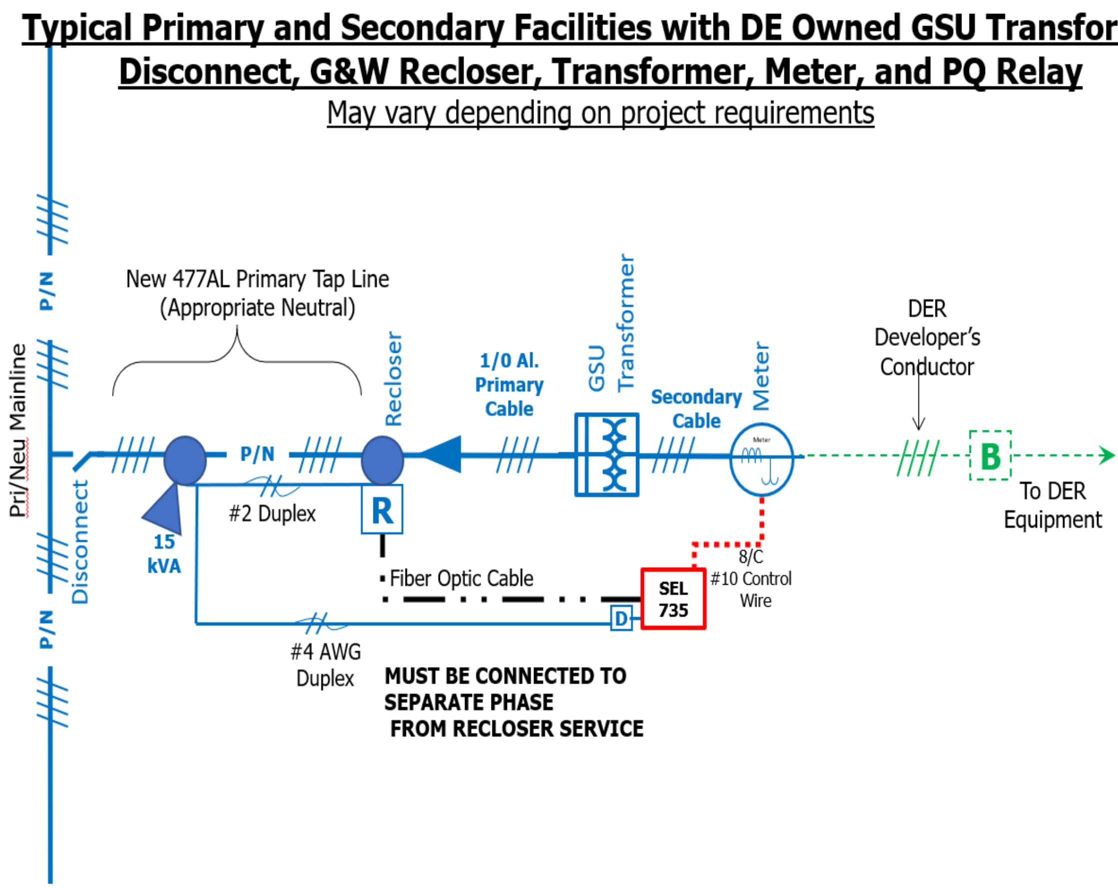


***Figure 3**: Typical Primary and Secondary Distribution Facilities Layout (Dominion owned transformer)*



APPENDIX B: ESS Application and Operating Modes

Application 1: Electric energy time shift

Definition: Charge and discharge the battery at different market price to gain benefit from the price difference in the wholesale electric energy market.

Type of Power: Active power.

Operating time of the day: Dependent on energy price differential, storage efficiency, storage variable operating cost, or avoided T&D costs.

Compatible applications: Electric supply capacity, T&D upgrade deferral, transmission congestion relief, electric service reliability, electric service power quality, and ancillary services.

Application 2: Electric Supply Capacity

Definition: Charge the battery when demand is low, discharge the battery when demand is in peaking hours to defer and/or to reduce the need to invest in base generation capacity for peaking demand and/or to purchase generation capacity output in the wholesale electricity marketplace.

Type of Power: Active power.

Operating time of the day: Peak demand hours for discharging, off-peak demand hours for charging.

Compatible applications: Electric energy time-shift, electric supply reserve capacity, regulation, voltage support, T&D upgrade deferral, transmission support and congestion relief, electric service power quality, and electric service reliability.

Application 3: Electric Supply Reserve Capacity

Definition: Battery is charged and does not discharge beyond its reserve capacity. It is ready and available to discharge reserve capacity if needed when some portion of the normal electric supply resources become unavailable unexpectedly.

Type of Power: Active power.

Operating time of the day: May occur at any time of the day.

Compatible applications: Cannot serve any other applications while providing reserve capacity. When not providing reserved capacity, the following applications can be served: electric energy time-shift, electric supply capacity, other ancillary services, renewables energy time-shift, renewables capacity firming, and wind generation grid integration. Depending on location, it could also be used for transmission congestion relief and T&D upgrade deferral.

Application 4: Load Following

Definition: Charge/discharge the battery to follow demand when system load decreases or increases to be operated in direct response to changing demand. Also maintain the scheduled system frequency.

Type of Power: Active power.

Operating time of the day: During the day and early evening (charge/discharge), during the night and early morning (charge/discharge).

Compatible applications: Renewable capacity firming, electric energy time-shift, and possibly electric supply reserve capacity applications. Most of the distributed applications are for voltage support.

Application 5: Frequency Regulation

Definition: Charge/discharge the battery when there are rapid load fluctuations to reconcile momentary differences between supply and demand. This maintains the grid frequency and assists in system recovery from system disturbances.

Type of Power: Active power.

Operating time of the day: May occur at any time of the day.

Compatible applications: Cannot be used simultaneously for other applications while providing regulation. When not in its primary application, can provide electric energy time-shift, electric supply capacity, electric supply reserve capacity, or T&D upgrade deferral.

Application 6: Voltage Regulation

Definition: Without charging/discharging the battery, the inverter provides reactive power to regulate grid voltage to solve over-voltage/under-voltage issues and stabilize system voltage as needed.

Type of Power: Reactive power.

Operating time of the day: May occur at any time of the day.

Compatible applications: Electric energy time-shift, electric supply capacity, other ancillary services, renewables energy time-shift, renewable capacity firming, and renewable generation integration. Distributed storage used for voltage support cannot be used for regulation though it could be used for most or all other applications.

Application 7: Blackstart

Definition: Charge the battery to have an active reserve of power. Does not discharge beyond its blackstart capacity when the battery is in blackstart only mode. The storage has to be ready and available to discharge after a catastrophic failure of the grid to energize transmission and distribution lines and provide station power to bring power plants online. The inverter has to be a grid-forming inverter.

Type of Power: Active power.

Operating time of the day: May occur at any time of the day.

Compatible applications: Cannot serve any other applications while providing blackstart reserve capacity. When not serving blackstart reserve capacity, electric energy time-shift, electric supply capacity, other ancillary services, renewables energy time-shift, renewables capacity firming, and wind generation grid integration are possible. Depending on location, it could also be used for transmission congestion relief and T&D upgrade deferral.

Application 8: Transmission Congestion Relief

Definition: Charge the battery when there is no transmission congestion, discharge it during peak demand periods to reduce transmission capacity requirements and the cost of more transmission capacity and increased transmission access charges. Also to reduce the use of congestion charges or locational marginal pricing (LMP) for electric energy.

Type of Power: Active power.

Operating time of the day: Peak demand hours.

Compatible applications: Electric energy time-shift, electric supply capacity, ancillary services, and possibly renewable energy time-shift.

Application 9: T&D Upgrade Deferral

Definition: Charge the battery when load is low, discharge the battery when highest load occurs to provide enough incremental capacity. This will result in a delay or avoidance of investments in transmission and/or distribution system assets (transformer, line, etc.) upgrades.

Type of Power: Active power.

Operating time of the day: Peak demand hours.

Compatible applications: Electric energy time-shift, electric supply capacity, electric supply reserve capacity, voltage support, transmission congestion relief, electric service reliability, electric service power quality, and renewable energy time-shift. If the storage is customer-owned, it may be compatible with TOU energy cost, demand charge management, electric service reliability, electric service power quality, and for renewables (co-located distributed PV) capacity firming.

Application 10: T&D Support

Definition: Discharge the battery when electrical disturbances occur to provide active power and reactive power support and reduce the transients in the system.

Type of Power: Active power/reactive power.

Operating time of the day: May occur at any time of the day when there is an event.

Compatible applications: Cannot be used concurrently with other applications. Nevertheless, storage used for transmission support during peak demand or peak congestion times could be used at other times for several other applications if the storage has the necessary discharge duration.

Application 11: TOU Energy Cost Management

Definition: Charge the battery during off-peak time periods when the electric energy price is low. Discharge the battery during times when on-peak TOU energy prices apply to reduce residential or medium sized commercial/industrial customers' overall costs for electricity.

Type of Power: Active power.

Operating time of the day: TOU energy prices apply.

Compatible applications: Demand charge management applications. It could also provide benefits associated with improved electric service power quality and electric service reliability. Similarly, depending on a plant's discharge duration and when discharge occurs, it may be compatible with T&D upgrade deferral applications.

Application 12: Demand Charge Management

Definition: Charge the battery when demand is low, discharge the battery when demand is high to reduce overall cost of electric service.

Type of Power: Active power.

Operating time of the day: Demand charges apply.

Compatible applications: Electric energy time-shift and ancillary services (if end users are allowed to participate in the wholesale energy marketplace). Transmission congestion relief, T&D upgrade deferral, TOU energy cost management, electric service power quality, electric service reliability, renewables capacity firming, and RE electric energy time-shift applications.

Application 13: EV Charging Integration

Definition: This application is very similar to peak shaving. Charge the battery during non-peak times. Discharge the battery when EVs are charging to reduce load demand during periods of high EV charging. This may also result in deferral of infrastructure upgrade.

Type of Power: Active power.

Operating time of the day: Peak demand hours for EVs.

Compatible applications: Time-of-use energy cost management, demand charge management, electric service reliability, and electric power quality.

Application 14: Electric Service Reliability

Definition: Battery is charged and does not discharge beyond its reserve capacity. Shall be available to discharge when there is a total loss of power from the source utility. This will provide highly reliable electric service for primary customers/critical load.

Type of Power: Active power.

Operating time of the day: May occur at any time of the day.

Compatible applications: Compatible with most applications except regulation. It is especially compatible with electric service power quality applications.

Application 15: Electric Power Quality

Definition: Charge the battery at a normal operating condition. Discharge the battery to improve customers' power quality in 1.2 cycles or less.

Type of Power: Active power/reactive power.

Operating time of the day: May occur at any time of the day.

Compatible applications: Time-of-use energy cost management, demand charge management. Electric service reliability is usually not a primary application for the system.

Application 16: Renewable Energy Time Shift

Definition: Charge the battery using low-cost energy from renewable energy (RE) generation. Discharge the battery when the energy price is higher. This will make it possible to benefit from the price difference in the wholesale electric energy market.

Type of Power: Active power.

Operating time of the day: Depends on renewable energy price differential, RE type, storage efficiency, and storage variable operating cost.

Compatible applications: Renewable capacity firming, electric supply capacity applications, electric supply reserve capacity, area regulation, voltage support, transmission congestion relief, T&D upgrade deferral, electric service power quality, electric service reliability, TOU energy cost management, and demand charge management.

Application 17: Renewable Energy Capacity Firming

Definition: Charge the battery during non-RE generation times. Discharge the battery when RE generates power to make the combined output from renewable energy generation plus storage less variable. The ESS system can partially or fully address short term RE output intermittency issue.

Type of Power: Active power.

Operating time of the day: During the time when RE generation sites operate.

Compatible applications: Renewable energy time-shift, electric supply reserve capacity applications. voltage support, transmission congestion relief, T&D upgrade deferral, TOU energy cost management, demand charge management, electric service reliability, and electric service power quality.

APPENDIX C: ESS Interconnection Configurations

This Appendix shows the typical ESS configurations. This is only an illustrative example of potential configurations and is not an exhaustive list. Dominion Energy may add or modify configurations in the future.

C1 AC connected ESS configurations

C1.1 Configuration 1A: Standby ESS

A standby ESS is intended to supply power to public, private facilities, or property. It can supply on-site generation to selected loads either automatically or manually. This ESS is typically embedded in the electrical system of the customer and typically has no direct electrical connection with Dominion Energy's EPS. The ESS does not operate in parallel with the utility. This configuration is commonly used in conjunction with a protected load panel that is normally fed from the main panel and can be fed by the standby system when the utility is unavailable. The ESS inverter is bi-directional with grid-forming capability. The ESS can be charged from either utility or self-generation. The ESS can only export power to its critical loads and will not export energy to the EPS.

This configuration will not require an interconnection study if appropriate measures/solutions are taken to prevent power from flowing to the grid (through documentation and testing) for open transitions. Closed transitions require review but may not require an Interconnection Agreement (IA) if it can be validated through documentation and testing that the standby system and utility are paralleled 100ms or less and with sufficient backup protection to ensure a prolonged paralleling condition does not occur. Finally, the block shown in Figure 1 below has a potential to form an island, as indicated by the note "Potential Island."

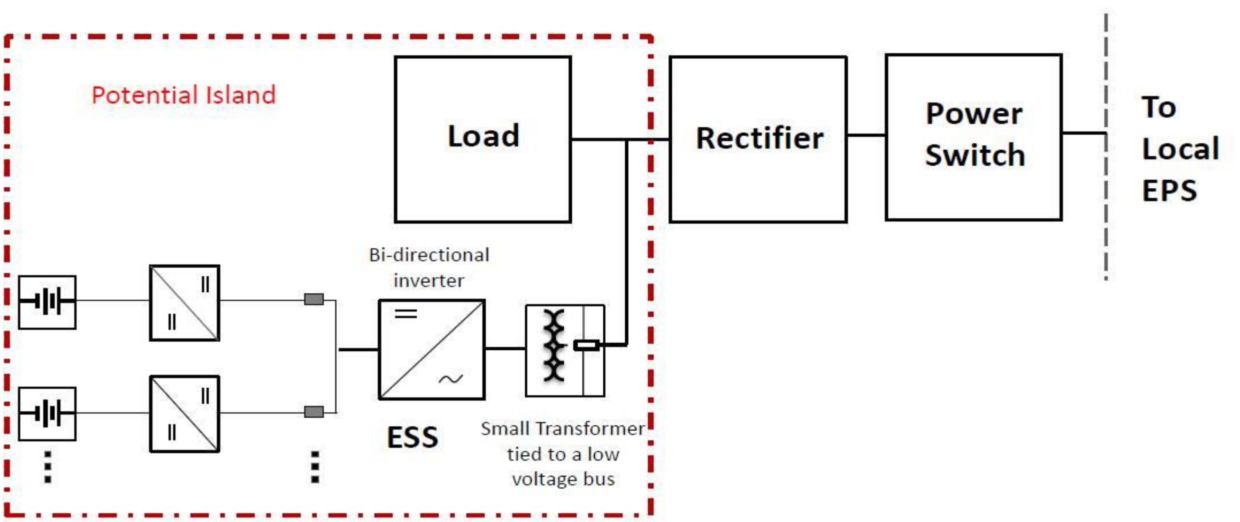


Figure 1: Stand-alone ESS (Configuration 1A)

C1.2 Configuration 1B: ESS for grid following

A grid following ESS is designed to have no other source than the utility. Charging is done exclusively using the utility source. For study purposes, Dominion Energy considers the grid following ESS as both a load and a generator. Therefore, the ESS will be subject to all of Dominion Energy's study parameters and associated interconnection requirements. The ESS inverter is a bi-directional grid following inverter. The battery system can be discharged for various applications as defined in Appendix B. Additional infrastructure configurations may be added to this configuration (e.g. EV charging station, load, etc.). This configuration is subject to the interconnection study process.

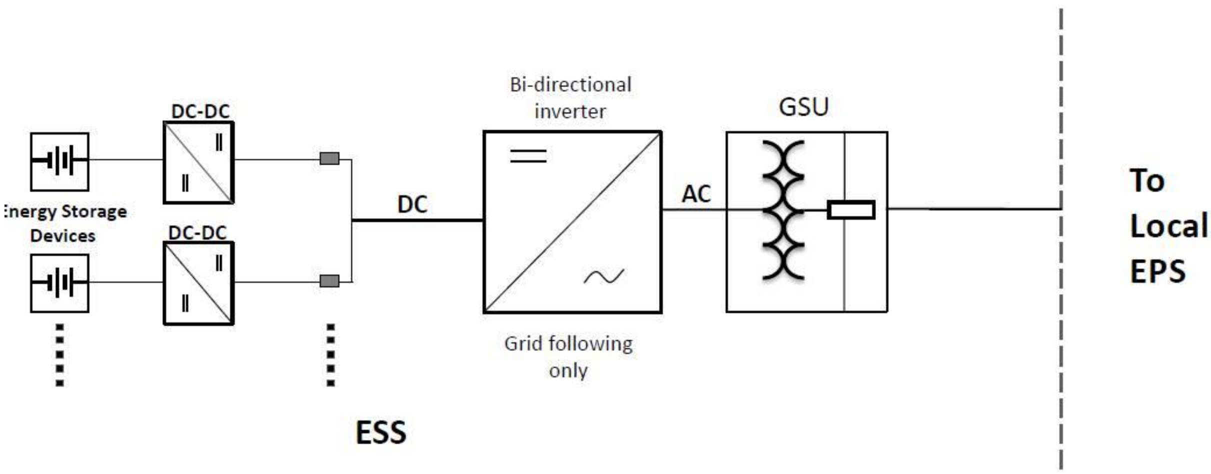


Figure 2: Grid-following ESS (Configuration 1B)

C1.3 Configuration 1C: ESS for grid forming and following

An ESS, for grid forming and following, is designed to have no other source than the utility. Thus, charging is done exclusively using the utility source. When a system outage occurs, the ESS can serve as a backup power source to the local load. For study purposes, Dominion Energy considers the ESS for grid forming and grid following as both a load and a generator. Therefore, the ESS will be subject to all of Dominion Energy's study parameters and associated interconnection requirements. The ESS inverter is a bi-directional grid forming and following inverter. The ESS can be discharged for the various applications defined in Appendix B. Additional infrastructure configurations may be added to this configuration (e.g., EV charging station, load, etc.). Finally, the block shown in Figure 3 below has a potential to form an island, as indicated by the note "Potential Island."

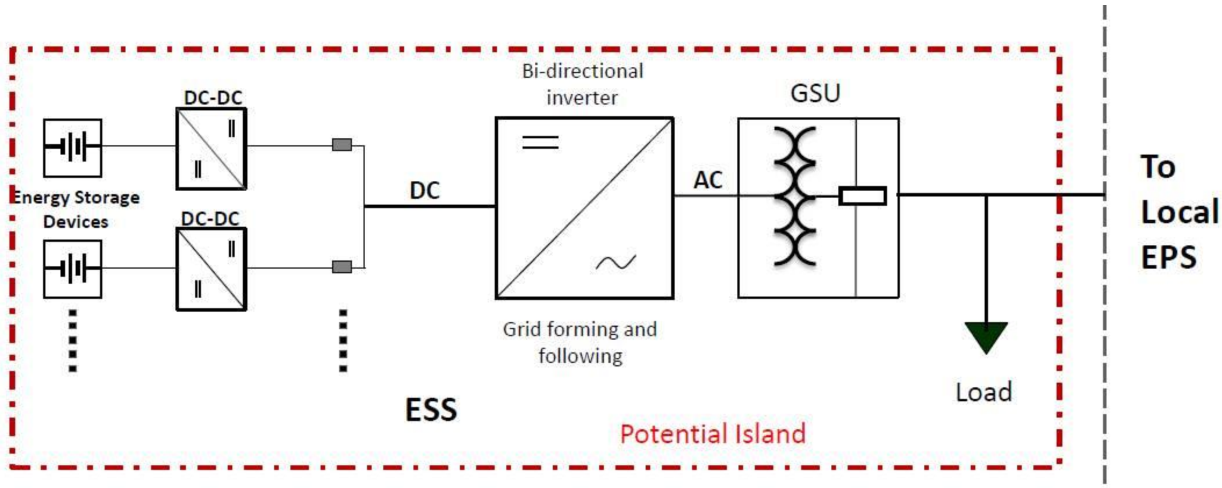


Figure 3: Grid-following ESS (Configuration 1C)

C2 AC coupled ESS configurations

C2.1 Configuration 2A: Standby ESS in a RE site

A standby ESS is intended to supply power to a RE site critical load. It can supply on-site generated or stored power to selected loads either automatically or manually. The ESS does not operate in parallel with the utility. The ESS can be charged from the utility or the renewable generation but may not supply power to the customer's load outside of standby operations. This configuration is commonly used in conjunction with a protected load panel that is normally fed from the main panel and can be fed by the standby system when the utility is unavailable. The ESS inverter is a bi-directional inverter with grid-forming capability. The ESS can only export power to its critical loads and cannot export energy back to the local electric power system. Finally, the block shown in Figure 4 below has a potential to form an island, as indicated by the note "Potential Island."

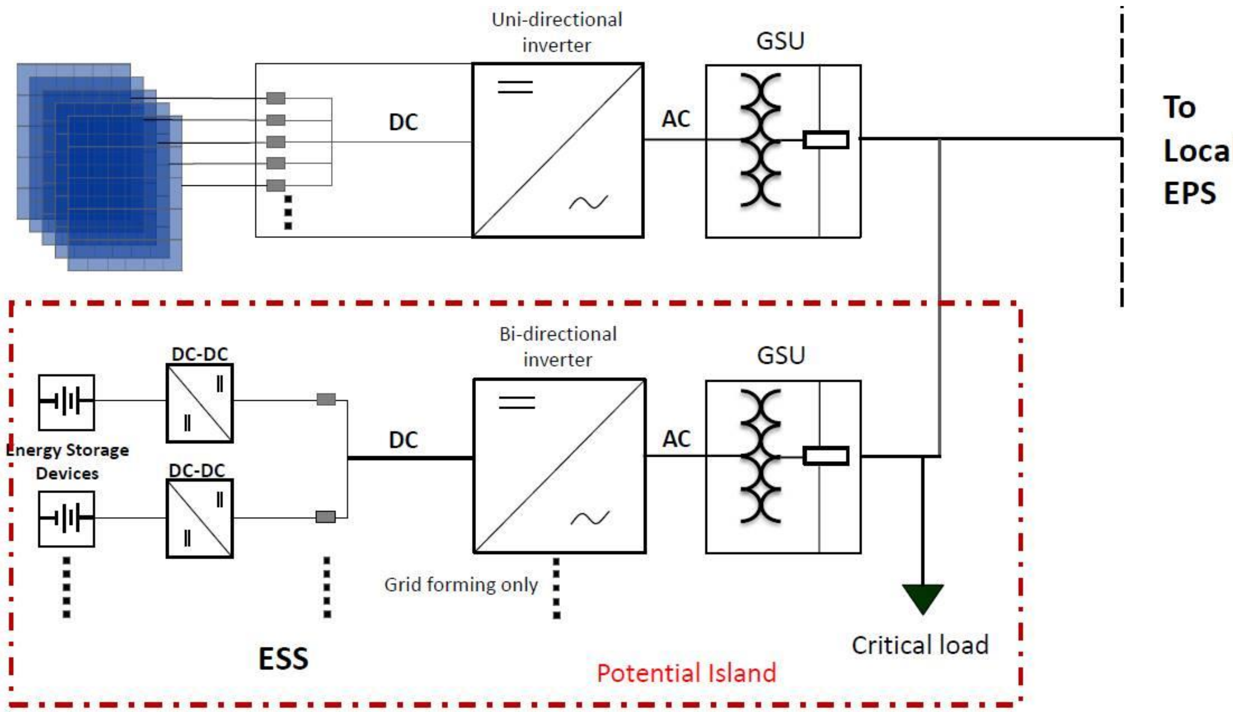


Figure 4: Standby ESS in a RE site (Configuration 2A)

C2.3 Configuration 2B: ESS paired with RE generation

An ESS paired with RE generation is an AC coupled ESS configuration that is designed to have an additional source other than the utility. The second source is typically a renewable source such as solar (PV). Thus, charging of the energy storage device can be done with either source. Since charging can be performed using the utility source, the AC coupled ESS is considered as both a load and a generator by Dominion Energy. Therefore, the ESS will be subject to all of Dominion Energy's study parameters and associated interconnection requirements.

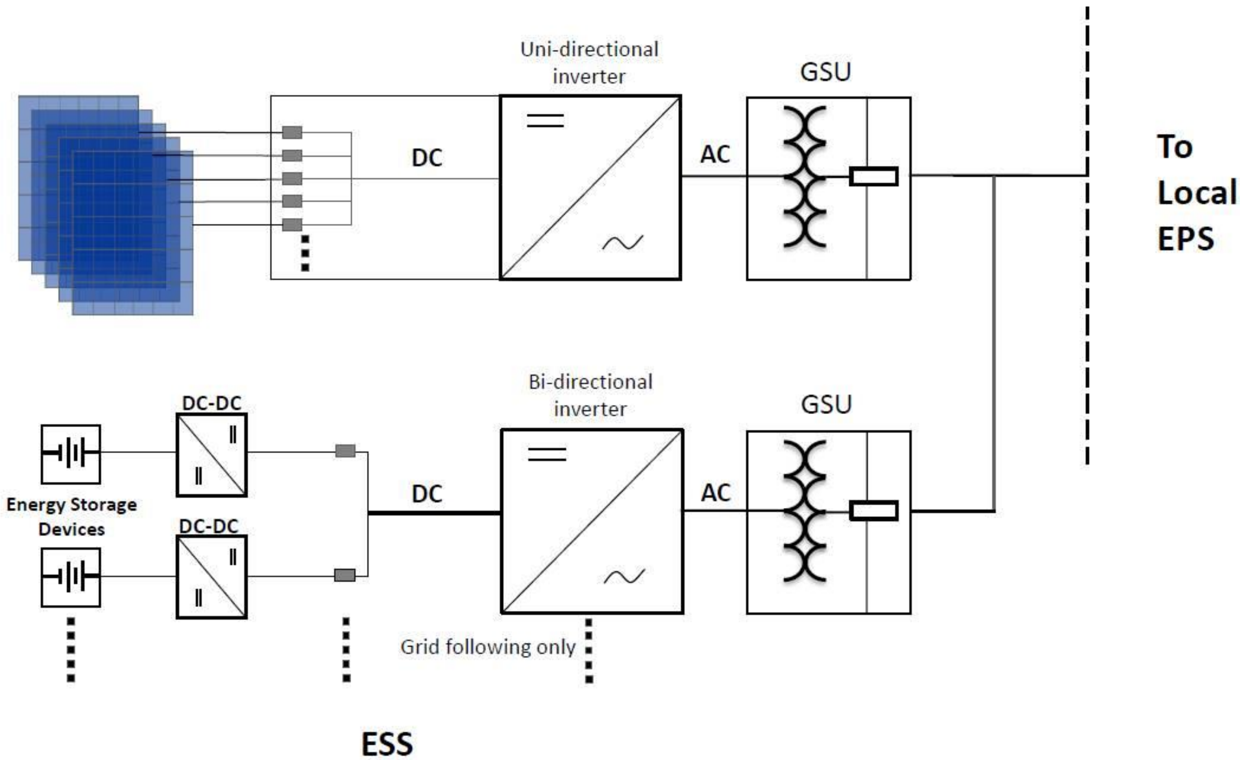


Figure 5: ESS paired with RE generation (Configuration 2B)

C2.4 Configuration 2C: ESS for a microgrid

In this configuration, the ESS is a component of a microgrid and is designed for the ESS inverter to have both grid-forming and grid-following capabilities. When the ESS is in the grid-following mode, it is considered as both a load and a generator by Dominion Energy. Therefore, the ESS will be subject to all of Dominion Energy's study parameters and associated interconnection requirements. Finally, the block shown in Figure 6 below has a potential to form an island, as indicated by the note "Potential Island."

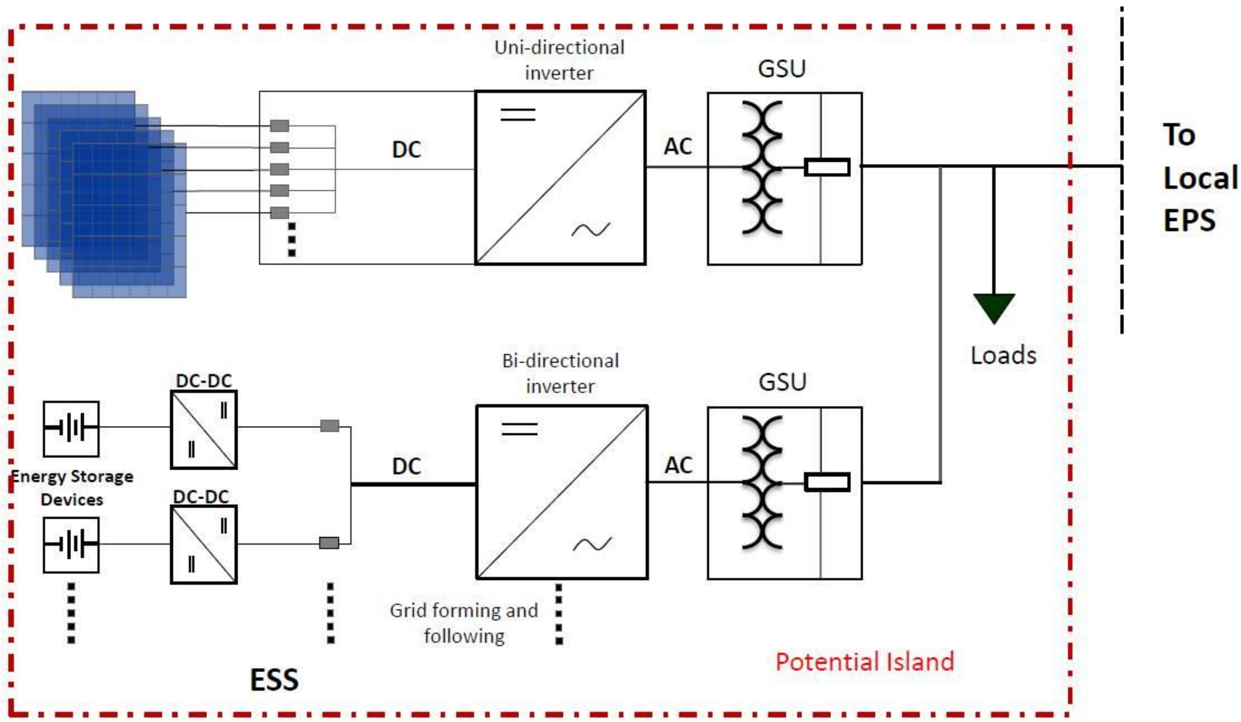


Figure 6: ESS for a microgrid (Configuration 2C)

C3 DC coupled ESS

C3.1 Configuration 3: DC coupled ESS

A DC coupled ESS consists of a uni-directional DC-AC inverter which is shared by both the ESS and the renewable resource (i.e., typically Solar PV). Although, the ESS's DC to DC converter is designed to be bi-directional, the design is such that the ESS can only be charged by the DC source. This configuration is subject to of Dominion Energy's DER interconnection study parameters.

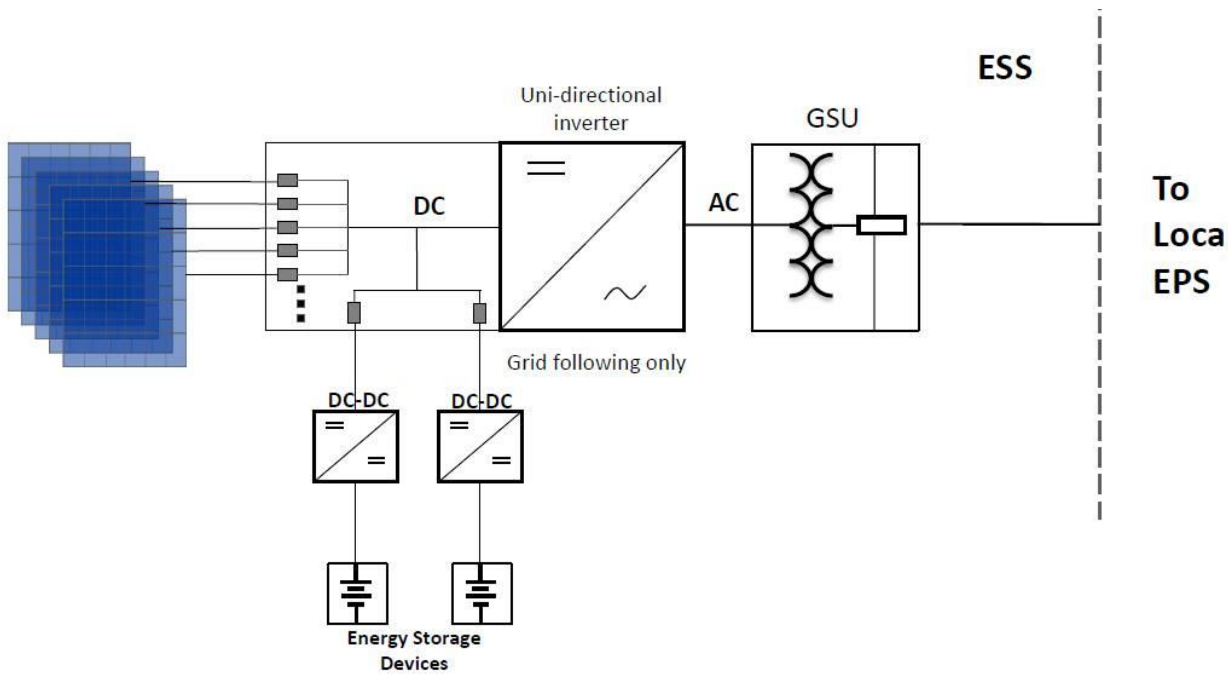


Figure 7: DC coupled ESS (Configuration 3)

APPENDIX D: Estimated Facilities Costs for Typical DER Upgrades

ESTIMATED FACILITIES COSTS REVISION HISTORY:

Facilities Costs type	Date	Revisions
Distribution Improvement	March 2021	Initial Release
Substation Improvement	February 2021	Initial Release
Distribution Improvement	January 2024	Update 2.0
Substation Improvement	January 2024	Update 2.0

Disclaimer:

The following cost estimates are not binding for actual facilities costs and are provided for informational purposes only to assist Developers in their planning for DERs. These cost estimates have not been determined in connection with any particular interconnection and are subject to change at any time by Dominion Energy. In addition, other substation upgrades and protection facilities that are not identified below may be required for transformers. The distribution and substation improvement estimates are for materials only; engineering, labor, and construction costs are adders. Notwithstanding these cost estimates, a Developer shall be responsible for the actual costs for any required distribution and substation improvements required for the interconnection of its DER.

Distribution Improvement:

1-Mile of Small 1-phase Wire Upgraded to 3-phase 477 AAC	\$ 700 - \$ 900K
1-Mile 3-phase Re-Conductor from Small Wire to 477 AAC	\$ 700K - \$1.1M
1-Mile Overhead Fiber Installation assuming 50% Pole Replacement	\$ 200K
1 Pole Replacement (typically 24 poles/mi)	\$ 8K - \$ 14K
Fiber Termination Box added to Existing SEL Recloser Control for Third Party Fiber Connection	\$ 15K
1-Mile Conversion to 34.5 kV - Same wire	\$ 700K - \$ 900K
1-Mile Over-build Existing Line with 477 AAC	\$ 900K - \$ 1.1M
1-Mile Conversion and Re-Conductor to 477 AAC	\$ 900K - \$ 1.1M
Adder[1] – Distribution Wire Upgrade, Overbuild, or Conversion (Engineering \ Mobilization \ Construction Management)	\$ 200K - \$ 400K

[1] This adder is applicable to the following distribution improvement work, and is not on a per mile basis:
- 1-Mile of Small 1-phase Wire Upgraded to 3-phase 477 AAC.
- 1-Mile 3-phase Re-Conductor from Small Wire to 477 AAC.
- 1-Mile Conversion to 34.5 kV - Same wire.
- 1-Mile Over-build Existing Line with 477 AAC.
- 1-Mile Conversion and Re-Conductor to 477 AAC.

Install New or Replace Existing Recloser with G&W Unit	$ 125K
Install New 1- 1-phase Regulator	$ 60K
Install New 3- 1-phase Regulators as a Bank	$ 125K
Adder[2] - Off-Road Work - 1- Mile - Varies	$ 400K - $ 800K
Adder[3] - Permit/Hours Restrictions - 1-Mile of Work - Varies	$ 80K - $ 120K
Adder[4] - 2000 Feet of Environmental Matting	$ 200K - $350K

Substation Improvement:

Adding New Circuit Breaker (34.5 kV) in Existing Bay	$ 200K - $ 500K
Adding New Circuit Breaker (34.5 kV) and Adding New Bay	$ 250K - $ 1M
Adding 115/34.5 kV, 20/27/33.6 MVA Transformer	$ 2.6M - $ 2.9M
Adding 230/34.5 kV, 20/27/33.6 MVA Transformer	$ 2.9M - $ 3.2M
Adding 230/34.5 kV, 33.6/44.8/56 MVA Transformer	$ 3.4M- $ 3.6M
Adding 230/34.5 kV, 50.4/67/84 MVA Transformer	$ 3.6 M - $ 4.2M
DG Relay Panel Only	$ 250K
Additional Typical Protection - Varies	$ 150 - $ 250 K
10-Foot Control Enclosure Expansion	$ 250K

[2] [3] [4] These adders could apply to any distribution improvement work.
[5] This adder is applicable to all substation improvement work.

New Control Enclosure	$ 800K
Adder[5] - TX Engineering \ Mobilization \ Construction Management	$ 200K - $ 1.2M
Add 1-Phase Line CCVT	$ 75K
Add 3-Phase Bus PTs	$ 250K
Adding Secondary Oil Containment for New TX	$ 300K
Add Distribution Cap Bank	$ 500K - $ 700K
Add New Transformer High Side Equipment	$ 250K - $ 750K