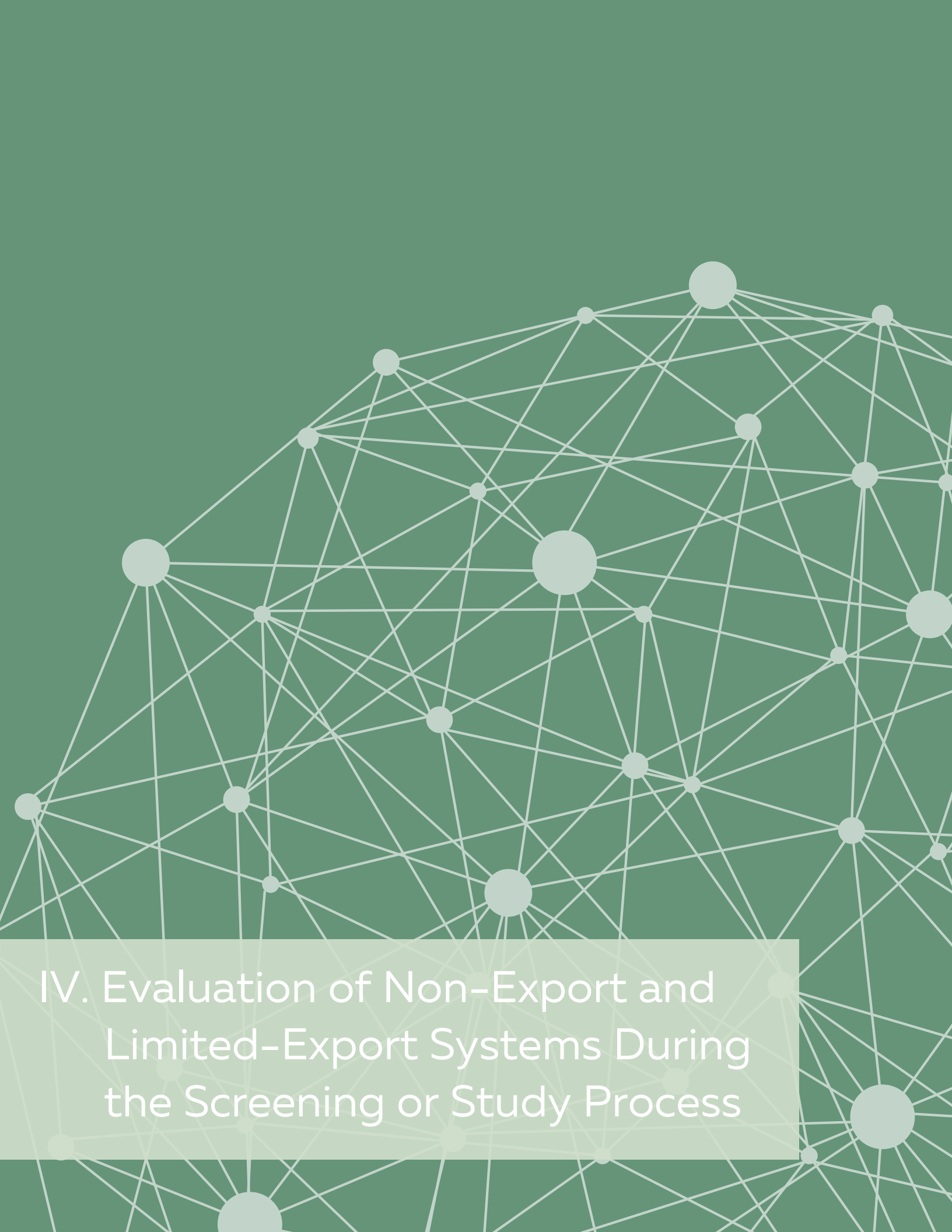

IV. Evaluation of Non-Export and Limited-Export Systems During the Screening or Study Process

IV. Evaluation of Non-Export and Limited-Export Systems During the Screening or Study Process

A. Introduction and Problem Statement

Exported energy is often a primary consideration in the screening and technical review of any grid interconnection application. When utilities evaluate the potential impacts of a proposed DER, they evaluate a variety of different technical criteria, including voltage impacts, protection, thermal constraints, and operational flexibility.[38] Most, but not all, of these factors are dependent upon how much power is exported by the DER.

With the exception of a few states where interconnection procedures have long recognized non-exporting systems, utilities typically assume that proposed DER projects always export their full Nameplate Rating, even if that DER project behavior is neither expected nor plausible. This often results in an overestimation of the impacts of a DER facility. The assumption of full export is particularly problematic for an ESS that is alternating current (AC)-coupled with onsite solar or other generation, as it results in the facility being studied as though the ESS exports at the same time as the solar asset, which is typically not how systems are programmed to operate because it does not make economic sense. (In some cases, there may be retail rate structures where on-peak times fall during solar production hours, making maximum battery discharge and solar exports advantageous.) However, interconnection safety review often needs guarantees of system operation even when adverse conditions are unlikely to occur and distribution system upgrades might result in excess capacity or protection. In addition, the assumption of full export ignores the ability of applicants to use managed charging as a solution to mitigate hosting capacity constraints.

In light of the growing number of areas with grid capacity constraints, some customers are choosing to install non-export or limited-export projects that can guarantee avoidance of system impacts when appropriately evaluated. Accepting the use of verified export controls and changing the way that the system is screened or studied will overcome a barrier to the interconnection of ESS that results in overestimating system impacts.

Chapter III addresses the first part of this barrier by providing recommendations on minimum requirements for export control methods. Establishing trusted methods of controlling export enables utilities to safely deviate from their default assumption that DERs export their full nameplate capacity. This chapter examines the screening and study processes on a project level when acceptable methods of export control are utilized.

[38] Electric Power Research Institute, *Analysis to Inform California Grid Integration Rules for Photovoltaics: Final Results on Inverter Settings for Transmission and Distribution System Performance*, (Dec. 2016) https://www.epri.com/research/products/000000003002008300; Electric Power Research Institute, *Impact Factors and Recommendations on how to Incorporate them when Calculating Hosting Capacity*, (Sept. 2018) https://www.epri.com/research/products/000000003002013381.

As discussed in Chapter III.B, non-export systems are already included in many interconnection procedures and many state procedures already require utilities to evaluate non-export projects more efficiently in light of the fact that they do not export. Only recently have procedures begun to recognize the concept of a limited-export system, however. This chapter addresses the manner in which the technical review process should take into account a project's export-limiting characteristics, whether they are non- or limited-export. It examines where export control enables and complicates interconnections and presents recommendations on how to alter the technical review process to incorporate equipment certified for export control into the interconnection technical review process.

B. Background on Technical Review Processes

Typical interconnection technical review processes apply a tiered review approach that offers multiple review paths which increase in complexity depending on the project's characteristics. This approach is utilized in FERC SGIP and a similar basic framework is used across state jurisdictions regardless of whether the process is modeled off of SGIP, IREC's Model, or another template. Most jurisdictions have both a screening and a study process.

The screening processes are designed to use a set of conservative screens to determine whether there is any probability that a project will result in distribution system impacts. If a project passes the screens, this indicates there is no need for a full interconnection study because there is little probability that it will cause distribution system impacts. Projects that fail the screens, or are not eligible for the screening process due to their size, proceed to a series of interconnection studies that more thoroughly analyze whether distribution system impacts will arise, identify whether upgrades are needed, and determine the costs of those upgrades if needed.

The screening process is often split into multiple different tiers as well. SGIP and most state procedures have an expedited pathway for small (10-50 kW) certified inverter-based projects (often called the simplified, expedited, or Level 1 process; for the remainder of this discussion, it will be referred to as the Simplified process). Some states use fewer screens in the Simplified process,[39] but SGIP and most states apply the same screens used for larger projects.[40]

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[39] IREC 2019 Model § III.A.2., III.B.2 (Level 1 uses fewer screens than Level 2); MA Dept. of Public Util., Eversource Energy, Standards for Interconnection of Distributed Generation, p. 47 (Sept. 15, 2021) (Figure 1 shows that the Simplified process uses fewer screens than expedited process), https://www.eversource.com/content/docs/default-source/rates-tariffs/55.pdf; 199 IA Administrative Code 45.8-45.9 (Level 1 uses fewer screens than Level 2).

[40] FERC SGIP, Attachment 5: Application, Procedures, and Terms and Conditions for Interconnecting a Certified Inverter-Based Small Generating Facility No Larger than 10 kW ("10 kW Inverter Process"), § 4.0 (simplified 10 kW Inverter Process uses the same screens as the Fast Track process); NC Util. Comm., Dkt. E-100, Sub 101, North Carolina Interconnection Procedures § 2.2.1 (Aug. 20, 2021) (Simplified 20 kW Inverter Process uses the same screens as Fast Track process), https://desitecoreprod-cd.azureedge.net/_/media/pdfs/for-your-home/212287/ncip-approved-oct-15-2020.pdf?la=en&rev=cd85b126dd0345019917e2464beb861b. UT Admin. Code R746-312-7 (Level 1 and Level 2 use the same screens).

The next tier is commonly known as the Fast Track or Level 2 process (hereinafter referred to as Fast Track). Under this process, the project is subject to an initial set of screens, and if it fails any of those screens, it may have the option to proceed to a Supplemental Review process. Some states and SGIP have defined screens for the Supplemental Review process, while in other states it is more open-ended.[41]

Some states also have a distinct process for non-exporting projects, often called the Level 3 process. Level 3 typically uses the same screens as Fast Track, but allows larger projects and may use a shorter review period.[42]

Projects that pass through any of the screening processes can go directly to an interconnection agreement, while those that fail have the option to withdraw or proceed to the full study process.[43] The full study process typically consists of a series of studies[44] that are designed to first assess the potential impacts of a project on the system and, if impacts are identified, to determine necessary upgrades and their costs.

In practice, Initial Review criteria are more conservative than Supplemental Review criteria, whereas detailed studies are designed to more closely simulate actual effects rather than approximating probable impacts through screening.

For the most part, the screens used in interconnection procedures today do not yet recognize whether a project has the capability to control and limit export. Each screen is designed to evaluate the risks of different types of distribution system impacts. How to modify a screen to accurately evaluate export-controlled projects varies based upon the impact the screen is assessing. Similarly, study processes also need to take into account a project's export limiting capabilities for the power flow analyses to accurately identify potential system impacts. The following sections analyze how the screening and study processes should be altered to take into account export-controlled projects. Where applicable, specific changes to interconnection rule language are recommended, using the FERC SGIP as a model. Recommendations for changes to today's current interconnection procedures are described at the end of each section, and the end of this

[41] 4 Code of CO Regulations 723-3, Rule 38655(d)(VI) (defining the Supplemental Review screens); North Carolina Interconnection Procedures § 3.4 (no defined Supplemental Review screens). FERC SGIP and IREC 2019 Model both define Supplemental Review screens. FERC SGIP § 2.4.4; IREC 2019 Model § III.D.

[42] 199 IA Administrative Code 45.7(3) (non-export DERs qualify for Level 3 review that includes fewer screens than Fast Track); Code MD Regs. 20.50.09.11(C)-(D) (Non-export DERs qualify for Level 3 review that includes most of the same screens as Fast Track, except the penetration screen uses 25% of peak load rather than 15% of peak load); AZ Administrative Code § R14-2-2623(B)-(C) (expedited process for small non-exporting DER using the same screens as Fast Track).

[43] Electric Power Research Institute, *Independent Assessment of Duke Energy's Fast Track Review Process for DER Interconnection*, (Oct. 2019) https://www.epri.com/research/products/000000003002017329.

[44] FERC SGIP has a series of three: feasibility, system impacts, and facilities. FERC SGIP §§ 3.3-3.5. Some states also provide for three distinct studies, though it is now becoming more common to eliminate the feasibility study and proceed directly to a system impacts study. NC Util. Comm., Dkt. E-100, Sub 101, North Carolina Interconnection Procedures §§ 4.3-4.5 (no feasibly study); MN Pub. Util. Comm., Dkt. E-999/CI-16-521, Order Establishing Updated Interconnection Process and Standard Interconnection Agreement, Attachment: Minnesota Distributed Energy Resources Interconnection Process (MN DIP) §§ 4.3-4.4 (Aug. 13, 2018) (no feasibility study); NJ Admin. Code 14:8-5.6 (no feasibly study). Some states, such as Nevada, have only a single study. NV Pub. Util. Comm., Dkt 17-06014, NV Power Co. Rule 15 (April 11, 2018).

chapter includes a compilation of model language that can be inserted into a state's interconnection procedures.

C. Recommendations

1. Verifying Export Control Methods

When an interconnection application is submitted, interconnection rules provide the utility with a period of time to review the application for completeness and to verify the screening or study process that the application will first be reviewed under. To ensure the evaluations can proceed once the application is received, interconnection application forms will need to be updated to include information about the ESS and, where export controls are used, the type of export control and the equipment type and settings that will be used (see Chapter VIII.B.1). The form should be updated to be inclusive of relays and other limited-export options. Where required, one-line diagrams should also note relay and sensor configurations and settings.

During this completeness review period and once the screening or study process commences, the utility should verify that the equipment used is certified (where necessary) and/or otherwise is acceptable for the intended use. When it comes to the export control methods, the utility should verify if the methods used meet the criteria identified in the export control section of the rule (as discussed in Chapter III). For example, the utility should verify whether the applicant is using a PCS that has been tested under UL 1741, and for relays it should verify whether the relay is utility grade.

Acceptable relay equipment is subject to utility-specific requirements which may be contained in handbooks or other addenda to technical interconnection requirements. Utilities may maintain preferred equipment lists of specific equipment types and model numbers, allowing developers to easily include acceptable equipment in initial applications. An engineering evaluation of the proposed DER may still be needed to ensure proper relay configurations and settings are noted. This can be done within the timelines associated with Fast Track or Impact Study reviews. Commissioning tests may include additional testing to ensure relays, PCS, or other export control devices are appropriately installed with the correct settings. As most interconnection procedures do not detail required commissioning steps, specific recommendations for tests of each different type of export limiting device are not provided within this Toolkit.

Finally, since export-controlled systems may contain equipment in addition to the generation or storage unit, such as relays or PCS, it should be clarified that these still qualify for the Fast Track process. Some states may restrict Fast Track eligibility to only certified inverters, and language regarding this eligibility should be inclusive of systems that control export using relays or non-certified control systems agreed to by the utility. Per SGIP attachments 3 and 4, relays are considered certified if they are tested by a NRTL to the IEEE C37.09.1 and C37.90.2 standards. Otherwise, SGIP subsection 2.1, Applicability, notes the Distribution Provider "has to have reviewed the design or tested the proposed

Small Generating Facility and is satisfied that it is safe to operate."[45] The latter option may be used for non-certified systems which are used under mutual agreement per the "Agreed-Upon Means" described in the recommendations of Chapter III.E.2.

2. Eligibility Limits for Screening Processes Should Reflect Export Capacity, Not Nameplate Rating

Screening thresholds are typically characterized in terms of a kW/kilowatt (kW) or megawatt (MW)/megavolt-ampere (MVA) rating without clearly specifying whether that rating refers to the Nameplate Rating or Export Capacity of a system, however, it is generally applied as a Nameplate Rating limitation.

a. Simplified Process Eligibility

As described above, FERC SGIP and most state DER interconnection processes have an expedited review pathway for small, certified inverter-based projects. Typically, these processes are limited to projects between 10 and 50 kW.[46] Projects in this size range generally pose little risk to the distribution system. Since the small projects are likely to pass the interconnection screens, these Simplified processes were created to more quickly screen the projects, and expedite the process for signing an interconnection agreement.[47]

Utilities process high volumes of small projects and, to avoid backlogs, it makes sense to have an efficient process in place for evaluating their impacts. Correspondingly, as the number of small projects that utilize export controls grows, it is reasonable to expect that many of these projects can also be safely reviewed under a Simplified process even if the Nameplate Rating of the project is larger than the existing size limit for the Simplified process. As long as a project's export is limited, the only impacts that might be seen from a project with a greater Nameplate Rating are those related to fault current. First, fault current contribution from DERs is far lower compared to the utility grid. Second, inverter-based DERs contribute a much smaller amount of fault current compared to rotating DERs. Third, putting a cap at 50 kW nameplate of inverter-based DERs further minimizes fault

[45] In Order 792, FERC explicitly clarified that projects are eligible for Fast Track review if the proposed project is certified *or* if it is has been reviewed by the utility and determined to be safe to operate. In other words, certification is not required for Fast Track review. Federal Energy Regulatory Commission, Docket No. RM13-2-000, Order 792, *Small Generator Interconnection Agreements and Procedures* (Nov. 22, 2013) (hereafter ""FERC Order 792"), ¶ 104 ("In doing so, the text of the Fast Track eligibility table will be consistent with section 2.1, which allows that Small Generating Facilities either be certified or have been reviewed or tested by the Transmission Provider and determined to be safe to operate.").

[46] NY Pub. Service Comm., NY State Standardized Interconnection Requirements, § I.B (March 2021), (using 50 kW); OH Admin. Code 4901:1-22-01(Z) (using 25 kW); 199 IA Administrative Code 45.7(1) (using 20 kVA); FERC SGIP, Attachment 5: 10 kW Inverter Process; UT Admin. Code R746-312-8(1)(b) (using 25 kW).

[47] Though this varies by state, the three major differences between a Simplified process and the Fast Track process are: (1) typically there is a combined application and agreement form that enables the customer to sign the agreement upon submitting the application, enabling the utility to simply counter sign after review is complete instead of sending it back to the customer for signature; (2) the timeline for application of the screens or other steps is sometimes shorter than that which is provided for Fast Track; and (3) in some states Simplified projects are processed through fewer screens.

contribution from such system sizes. Since PV with AC-coupled ESS would increase the Nameplate Rating, it is reasonable to allow limited-export systems with a larger Nameplate Rating to take advantage of this expedited process.

As described above in Section IV.B, eligibility limits for "Simplified processes" range from 10-50 kW. While many states are still using the lower end of the range (10 kW), the IREC 2019 Model uses 25 kW and the clear trend is to increase the threshold. For example, California uses 30 kVA; Maryland, Minnesota, and North Carolina use 20 kVA; and New York uses 50 kVA.[48] As such, applications should be permitted to utilize the Simplified pathway for certified inverter-based projects if the Nameplate Rating does not exceed 50 kW and the Export Capacity does not exceed 25 kW.

b. Fast Track Process Eligibility

Eligibility for the Fast Track process is also typically limited by size. SGIP originally limited access to projects below 2 MW, but in 2014 FERC updated SGIP to vary the eligibility by size for certified inverter-based systems depending on the "voltage of the line and the location of and the type of line at the Point of Interconnection."[49] The eligibility limit remained 2 MW for synchronous and induction machines (such as those powered by fossil fuel, hydro, bio/landfill gas, or through combined heat and power). Some states have followed the updated SGIP approach and adopted a varying eligibility limit, while others continue to have a single size limit for Fast Track eligibility. Regardless of the approach, like with the Simplified process, it is reasonable to apply the size limit to the Export Capacity instead of the Nameplate Rating.

Export-controlled projects may pass the screens that evaluate if a project is likely to cause safety or reliability impacts on the distribution grid, even if their Nameplate Rating is greater than the currently specified size limits. If a project passes through the screens, it can be safely interconnected without the need for further study. Enabling the greatest number of ESS projects to take advantage of this process is an important way to improve the efficiency and lower the costs of ESS interconnection. The following sections will discuss how each screen should be crafted to ensure that the impacts of export-controlled systems are accurately taken into account. The eligibility limit does not take the place of the screens and thus should only be used to sort out projects that are very unlikely to pass the screens.

Fast Track eligibility should be modified so that it is evaluated on the basis of the project's Export Capacity and not the Nameplate Rating of the project.

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[48] CA Pub. Util. Comm. Decision 20-09-035, pp. 43-44 (approving proposals 8f, 8g, 8h, and 8j, which increase the size limit for projects that can bypass certain screens from 11 kVA to 30 kVA; the final version of Rule 21 is still in the advice letters stage due to other issues but this change is supported by all parties and was ordered by the Commission); Code MD Regs. 20.50.09.08(B); MN Pub. Util. Comm. Dkt. E-999/CI-16-521, MN Distributed Energy Resources Interconnection Process § 2.1.1 (MN DIP) (April 19, 2019); NC Util. Comm., Dkt. No. E-100, Sub 101, North Carolina Interconnection Procedures, Forms, and Agreements for State-Jurisdictional Generator Interconnections, § 2.1 (Aug. 20, 2021); NY State Pub. Serv. Comm., Dkt. No. 15-E-0557, Order Modifying Standardized Interconnection Requirements (March 18, 2016).

[49] FERC SGIP § 2.1; FERC Order 792, ¶¶ 112-118 (describing why FERC raised the size limit for Fast Track eligibility).

3. Screens Require Modifications so the Impact of Export-Controlled Systems Is Accurately Evaluated

Each of the interconnection screens is designed to evaluate whether there is a risk that a proposed project will cause a particular type of impact on the distribution system. The screens cover a variety of different concerns, including thermal, voltage, protection, grounding, networks, etc. Some of the screens evaluate a project's likely impacts based upon the "size" of the project and, though the screens are not explicit, it is generally assumed that the size refers to the Nameplate Rating of the project. Unfortunately, in the case of export-controlled projects, applying certain screens using a project's Nameplate Rating instead of its actual Export Capacity can result in an overestimation of the project's impact. Thus, one of the single most important ways that the interconnection process can be improved for ESS projects is to ensure that each screen is written to properly distinguish between the impacts of a project with or without export control. This can primarily be done by distinguishing between the Nameplate Rating or the Export Capacity of a project depending on the type of potential impact the screen is intended to assess.

Two relevant definitions from Chapter II.B.3 are useful to note here as they will be referred to in this section:

- ***Export Capacity*** means the amount of power that can be transferred from the DER to the Distribution System. Export Capacity is either the Nameplate Rating, or a lower amount if limited using an acceptable means identified in Section 4.10 (to refer to section on acceptable export controls, see Chapter III.E).
- ***Nameplate Rating*** means the sum of maximum rated power output of all of a DER's constituent generating units and/or ESS as identified on the manufacturer nameplate, regardless of whether it is limited by any approved means.

Whether and how the screens need to be modified depends on the type of impact that each screen is designed to evaluate. The following subsections will discuss the screens that require revision to better accommodate the export control features of ESS. The screens referenced are those used in SGIP, which are also widely used across the United States. If a state has additional screens not identified herein, a similar analysis can be conducted for those screens to determine if the impacts they are designed to evaluate are related to the entire nameplate of a project or only the amount that is exported onto the distribution system. The SGIP screens that are not identified below do not require revision.

a. Screens in Which Export Capacity Is Appropriate to Use When Assessing Impacts

i. Penetration Screens

SGIP and most interconnection rules have what is known as a penetration screen in both the Simplified and Fast Track processes (typically the same screen) and SGIP also has a less conservative penetration screen in Supplemental Review. In SGIP, these are Fast Track screen 2.2.1.2 (known as the 15% of peak load screen) and Supplemental Review

screen 2.4.4.1 (known as the 100% of minimum load screen). Both of these screens are designed to evaluate if the total generation—currently normally applied based on the Nameplate Rating of each DER—on the line section exceeds the minimum load on the circuit (thereby creating the potential for backfeed).[50]

For both of these screens, it is appropriate to switch from Nameplate Rating to evaluating whether the proposed project's Export Capacity, aggregated with the Export Capacity of all other DERs on the line segment or circuit, exceeds the percentage of peak or minimum load. The intent of this clarification of terms is that only export past the Point of Interconnection is relevant to consider, as only that export amount would interact with the other load on the circuit. The penetration screens are used as a barometer for a range of potential issues that might arise when there is reverse power flow beyond the circuit or line section. As a result, when a system is designed to not export or to limit export, it is not necessary to consider the power that is not exported in this screen.

For projects with some amount of inadvertent export, we recommend a new screen to evaluate for potential impacts; this is discussed in the following section.

The penetration screens should be revised to clarify that the screen will be applied by evaluating the Export Capacity from the proposed project, not the full Nameplate Rating of the project.

ii. New Inadvertent Export Screen

If the steps described above for revising the eligibility limits to apply to Export Capacity (addressed in Chapter IV.C.2) and revising the Fast Track penetration screen (the 15% screen) to account only for Export Capacity (addressed in Chapter IV.C.3.a.i) are both taken, this could enable projects with any sized nameplate capacity to be interconnected without undergoing Supplemental Review or detailed impact studies (assuming the project does not fail any of the other Fast Track screens). The 15% screen is used as a proxy for reviewing voltage and other system effects. Any steady-state voltage rise due to reverse power flow would continue to be effectively evaluated under the 15% screen since the exported power that could cause reverse flow would still be accounted for. However, non-exporting DER capacity could also potentially introduce voltage changes due to inadvertent export events. As these short-term voltage effects would be dependent on only the non-exporting portion of the Nameplate Rating, the revisions to the 15% screen could mean that there is a possibility that these voltage changes would not be effectively screened. The non-exporting portion is the Nameplate Rating minus the Export Capacity.

The research team determined a sizing threshold below which a system would not create objectionable voltage changes due to inadvertent export. Above that threshold, an additional screen is recommended to ensure that inadvertent export from large systems

[50] Kevin Fox, Sky Stanfield, et al, *Updating Small Generator Interconnection Procedures for New Market Conditions*, Nat. Renewable Energy Laboratory, pp. 22-24 (Dec. 2012) (explaining the development and use of the 15% of peak load screen and the 100% of minimum load screen), https://www.nrel.gov/docs/fy13osti/56790.pdf. Note that existing DER may mask load, such that measured minimum net load is reduced. Backfeed will occur once aggregate generation exceeds the gross load.

does not pass through Fast Track without further evaluation. While this new screen is written to focus on evaluation of potential voltage violations, it will effectively also screen for any thermal constraints because voltage effects will arise prior to any thermal constraints being reached. Potential voltage and thermal effects of inadvertent export are described further in Chapter V. This screen is only necessary for those projects which use an export control method that may introduce inadvertent export (these methods are identified in Chapter III.E.2 in the recommended language for SGIP section 4.10.4).

The proposed screen is as follows and is explained below:

> *2.2.1.3 For interconnection of a proposed DER that can introduce Inadvertent Export, where the Nameplate Rating minus the Export Capacity is greater than 250 kW, the following Inadvertent Export screen limit is required. With a power change equal to the Nameplate Rating minus the Export Capacity, the change in voltage at the point on the medium voltage (primary) level nearest the Point of Interconnection does not exceed 3%. Voltage change will be estimated applying the following formula:*

Formula	$\frac{(R_{SOURCE} \times \Delta \boldsymbol{P}) - (X_{SOURCE} \times \Delta \boldsymbol{Q})}{V^2}$
Where: $\Delta \boldsymbol{P}$ = (DER apparent power Nameplate Rating – Export Capacity) × PF, $\Delta \boldsymbol{Q} =$ (DER apparent power Nameplate Rating – Export Capacity) × $\sqrt{(\boldsymbol{1 - PF^2})}$, R_{SOURCE} is the grid resistance, X_{SOURCE} is the grid reactance, V is the grid voltage, PF is the power factor	

The short-term voltage effects of inadvertent export, which take place over seconds, are akin to Rapid Voltage Changes (RVC), described by IEEE 1547-2018.[51] To ensure RVC is limited to no more than 3%, in line with the standard, even when a large nameplate capacity is behind a non-exporting control system, an estimate of voltage change can be made. This can be done using the primary grid impedance values from the circuit model in addition to the DER apparent power Nameplate Rating and Export Capacity. This calculation gives a close estimate of the actual voltage change. It is anticipated that most utilities will be able to access grid impedance data with reasonable efforts during Initial Review.

Simplified inputs may be used in the alternative, namely the DER Nameplate Rating, Export Capacity, and the short circuit capacity available at the medium voltage node nearest the

[51] IEEE 1547-2018 subclause 7.2.2 limits Rapid Voltage Changes at medium voltage to 3% of nominal voltage and 3% per second averaged over a period of one second.

Point of Interconnection.[52] As further described below, the project team evaluated a number of feeders, and this simplified calculation results in a rather conservative estimate of voltage change, especially nearer to the substation. Actual voltage change should be on the order of 50% or less of the calculated value. Thus, if a utility demonstrates that accessing the grid impedance data is not possible during Initial Review, voltage change may alternately be estimated by dividing the Nameplate Rating minus the Export Capacity by the short circuit capacity at medium voltage. However, this less precise approach is not recommended to be utilized in the interconnection rules unless the grid impedance data is truly inaccessible to a utility with reasonable efforts.

To limit the need to apply this screen to systems where there is little chance of voltage impact, the project team completed a review of the calculation for a large selection of feeders. No change lower than 298 kW triggered a calculation of more than 3% at the end of an "average" 12 kilovolts (kV) medium length feeder, and detailed calculations showed a maximum change of 368 kW. For a longer 4.2 kV feeder, the calculation was maintained within the limit up to 413 kW, with detailed calculations finding a maximum change of 574 kW. Therefore, it is reasonable to assume compliance without the need of running the calculation for systems with a non-exporting capacity below 250 kW. As inadvertent export events are generally non-coincident, the inadvertent export should be evaluated for only the DER system being interconnected. Further description of the analysis of this screen is provided in Appendix C.

If a project fails the 3% voltage change screen in Initial Review, the application will be subject to Supplemental Review. The voltage change due to inadvertent export can be further evaluated in a more detailed manner in Supplemental Review, by using the Nameplate Rating minus Export Capacity in the detailed estimate if the simplified estimate was used in Initial Review (described further in Appendix C) or through modeling. For DERs on shared secondaries, the 5% RVC criterion can be further evaluated at low voltage. For PCS with open loop response times shorter than 30 seconds, further voltage evaluations for inadvertent export should be unnecessary. For instance, as long as the OLRT is short compared to the delay of any voltage regulators present, there will be low likelihood of additional tapping of the regulator ascribed to the inadvertent export event. See section V.D for further description of regulator impacts.

A new screen in Initial Review (inserted as a new 2.2.1.3 in SGIP) should be introduced to further analyze the voltage effects of inadvertent export from systems that control export.

iii. Transformer Rating Screen

SGIP and most state interconnection procedures have a screen that evaluates whether a project interconnected to a single-phase shared secondary will create a risk of continuous equipment overloads or voltage issues caused by reverse power flow (SGIP screen 2.2.1.8). Like with the penetration screens discussed above, since the screen is designed to

[52] Note that "Point of Common Coupling" is referred to as "Point of Interconnection" in many interconnection procedures, and throughout this Toolkit.

evaluate the potential for reverse power flow to cause impacts, it is appropriate to evaluate this screen using only the aggregate Export Capacity and not the full Nameplate Rating of the proposed project and other already interconnected DERs.

The transformer rating screen should be revised to clarify that the aggregate generation evaluated should be the aggregate Export Capacity and not the full Nameplate Rating of the projects on the shared secondary.

b. Screens Where Evaluation Is Not Impacted by Export Controls

i. Spot Network Screen

Screen 2.2.1.3 in SGIP evaluates the ratio of DER penetration to a spot network's maximum load. Due to particular sensitivities of network protectors to reverse flow in a spot network, it is appropriate to use Nameplate Rating for this screen. The time responses of the export control methods may be insufficient for networks without re-configuration of the network protection.

ii. Fault Current and Short Circuit Contribution Screens

SGIP and most state rules have two screens that evaluate the potential effects of fault current impacts on the distribution system. SGIP screen 2.2.1.4 evaluates whether the proposed facility will significantly contribute to the maximum fault current on the distribution circuit. Screen 2.2.1.5 evaluates whether the proposed facility could cause fault currents to exceed the short circuit interrupting capability of electric distribution equipment.

While the export control methods identified in Chapter III.E.2 may act to limit the steady-state export from a site, they do not alter the transient behavior of the DER. During faults and other transient conditions, export controls are not typically fast enough to change the behavior of an export-controlled system. The fault current contribution from DER sites is therefore an aggregate contribution of the individual DERs.

Thus, during the screening and study process, utilities must still evaluate the fault current contribution from export-controlled projects. Where fault current is already high on a circuit, this means that export controls are not likely to avoid protection impacts in the same way that they might avoid exacerbating voltage or thermal constraints.

With higher DER penetrations, aggregate fault current, and its impact on protection systems coordination, is likely to become a more common limiting factor. This may not result in mitigation or system upgrade requirements but as penetration increases, more projects will likely fail the fault current screens and require further evaluation in Supplemental Review or Study.

Because of the way the screens are currently worded, there is not a need to modify the fault current screens in Initial Review to take into account the distinction between Export Capacity and Nameplate Rating like there is for other screens. However, it is

recommended that the fault current screens be modified to clarify that the rated fault current of the proposed DER is what is being evaluated. In addition, the SGIP Supplemental Review screen 2.4.4.3 and the SGIP system impacts study process section 3.4.1 should also be modified to further clarify that while Export Capacity should be used for assessing certain other types of distribution system impacts, the rated fault current should be used for assessments of fault current contribution.

Today, inverters are not generally programmed to limit fault current. However, due to their flexible and fast-acting nature, the possibility is left open that fault current could be affected by some programmable means. Where manufacturers are able to do so and provide test data noting any effects, fault current other than rated fault current could be considered in the review.

The fault current screens in Simplified, Fast Track, and Supplemental Review should be revised to clarify how fault current contributions are to be determined for all systems, including those that limit export. In addition, as described further in Chapter IV.C.4, the study process should also clarify how fault current will be evaluated for export-controlled systems.

iii. Service Imbalance Screen

SGIP screen 2.2.1.8 evaluates whether a facility could create an imbalance on the service if it only operates on one leg of the two-leg phase. Here, the full Nameplate Rating could contribute to this imbalance, so the service imbalance screen should be revised to clarify that the Nameplate Rating of a DER should be used.

iv. Transient Stability Screen

SGIP screen 2.2.1.9 evaluates whether a proposed project will contribute to any existing transient stability limitations in the area. This screen should be evaluated using a DER's Nameplate Rating because the transient behavior would be relative to the total Nameplate Rating of the system.

4. Study Process Modifications to Accommodate Export Control Capabilities

Most interconnection rules provide limited detail on how project impacts are evaluated in the full study process. However, as with the screening process described above, interconnection studies do need to take into account the manner in which a project has limited export when assessing impacts in the system impact study. In particular, if the proposed project is utilizing one of the acceptable means of export control (*i.e. those outlined in Chapter III.E.2*), then the utility should evaluate impacts to the distribution system using the project's Export Capacity, except when evaluating fault current effects.

When evaluating potential fault current impact, typically utilities use the Nameplate Rating of the project to calculate its contribution to fault current (see discussion above in Chapter

IV.C.3.b.ii). However, if the interconnection customer has provided manufacturer test data to demonstrate that the fault current is independent of the Nameplate Rating, then the utility should utilize the rated fault current instead.

In addition, if the project has proposed to use an operating schedule (instead of a fixed export limit), the feasibility study and system impact study should take that profile into account if the utility has assurances that the scheduling equipment can be relied upon. This is discussed more in the following subsection and in Chapter IX. The Facilities Study typically does not evaluate system impacts, therefore we do not recommend modifications to the Facilities Study.

Section 3.4.1 of SGIP (or the equivalent section describing the system impact study), the system impact study agreement, and the feasibility study agreement (if the state has not eliminated the feasibility study) should be modified to require use of Export Capacity in the study evaluation where appropriate export controls are used; designate the use of Nameplate Rating or the rated fault current (if different) for evaluation of fault current; and require consideration of a project's operating profile.

5. Reviewing ESS With Proposed Operating Profiles

As described in Chapter I.A.1, applicants may have a variety of different reasons for incorporating export controls into their project. In some cases, projects will seek to be evaluated on the basis of a fixed export limit (essentially a uniform "do not exceed" profile). Other projects may want to be evaluated in a more granular manner using a defined operating profile that varies throughout the day or by season, particularly if that profile is designed with the intent of avoiding specific hosting capacity limitations. Currently, utilities typically only evaluate projects assuming a uniform Export Capacity for all hours. Some utilities may recognize that solar PV projects (without storage) only operate during daylight hours in the screening process, but the extent to which the full solar output profile is considered in the study process is not well defined and likely varies based upon a utility's study capabilities.

In order for the interconnection process to fully recognize the manner in which ESS projects can be designed and controlled to avoid grid constraints, utilities will need to consider operating profiles in their impact assessments. Chapter IX discusses the manner in which schedules can be defined, communicated to the utility, and the steps that may be necessary to take in order for utilities to be confident that the schedule will be complied with (similar to how they need confidence that the export control method itself is reliable).

If that confidence can be established, then the technical review process may also need to change in order to evaluate grid conditions on an hourly or seasonal basis that corresponds to a project's proposed operating profile. Although changing interconnection review processes from annual to hourly evaluations is a big step to take, as DER proliferation increases, this process modernization is necessary to avoid overspending on

distribution upgrades. It is likely that further work will need to be done to thoroughly define the process for reviewing projects with operating profiles in interconnection procedures.

The interconnection screens used in most states are currently not granular enough to capture the nuances of an operating profile. However, they could be updated to include a more temporally-specific analysis for certain screens. For example, where states have more granular minimum load data available, a project could be screened in relation to the hours of export under SGIP's 100% of minimum load screen (screen 2.4.4.1). Alternately, as discussed in Chapter VI.B.2.b, the utilization of hosting capacity analyses in the screening processes could enable screening based upon operating profiles, as the California Public Utilities Commission has authorized.[53]

Turning to the study process, typically, the output of the DER is modeled in a time-varying load flow analysis. If the operating profile is not known, a worst-case impact will be assumed. However, when an operating profile is provided in an appropriate format and is controlled by methods the utility considers reliable (see Chapter IX for further discussion on validation of operating schedules), then the utility should be required to modify the analysis to incorporate the operating profile in the power flow simulations used to assess system impacts to the extent it has the capability to do so. Utilities will likely need to expand their capabilities as operating profiles become more common.

At this time, it is recommended that interconnection rules be updated to require feasibility studies and system impact studies to take into account the DER's proposed operating profile (where verifiable).

In addition, interconnection rules should require use of the operating profile in the system impact study agreement and the feasibility study agreement (if the state has not eliminated the feasibly study). It is expected that further development of utility screening and study practices will need to occur as scheduling capabilities evolve, but deeper analysis and recommendations are beyond the scope of the BATRIES project.

6. Proposed Revisions to Rule Language

The following revisions and additions to SGIP are recommended to implement the changes described above in this chapter. SGIP is used as the reference model, but these changes should be relatively easy to translate to most state interconnection procedures. Screens that are not modified are not shown.

[53] CA Pub. Util. Comm., Dkt. R.17-07-007, Interconnection of Distributed Energy Resources and Improvements to Rule 21, Decision 20-09-035, Decision Adopting Recommendations from Working Groups Two, Three, and Subgroup, pp. 36-48 (Sept. 30, 2020) (authorizing the use of hosting capacity analysis in the interconnection screening process).

Eligibility for Simplified/Expedited/Level 1 Screening Process

For Simplified processes, allow projects with a Nameplate Rating of up to 50 kW and an Export Capacity of up to 25 kW.

Fast Track and Supplemental Review

2.1 Applicability

The Fast Track Process is available to an Interconnection Customer proposing to interconnect its DER ~~Small Generating Facility~~ with the ~~Transmission Provider's~~ Distribution System if the DER ~~Small Generating Facility's~~ Export ~~c~~Capacity does not exceed the size limits identified in the table below. ~~Small Generating Facilities below these limits are eligible for Fast Track review.~~ However, Fast Track eligibility is distinct from the Fast Track Process itself, and eligibility does not imply or indicate that a ~~Small Generating Facility~~ DER will pass the Fast Track screens in section 2.2.1 below or the Supplemental Review screens in section 2.4.4 below.

Fast Track eligibility is determined based upon the ~~generator~~ DER type, the Export Capacity ~~size~~ of the ~~generator~~ DER, voltage of the line and the location of and the type of line at the Point of Interconnection. All ~~Small Generating Facilities~~ DER connecting to lines greater than 69 kilovolts (kV) are ineligible for the Fast Track Process regardless of Export Capacity ~~size~~. All synchronous and induction machines must have an Export Capacity of ~~be no larger than~~ 2 MW or less to be eligible for the Fast Track Process, regardless of location. For certified inverter-based systems, the size limit varies according to the voltage of the line at the proposed Point of Interconnection. Certified inverter-based ~~Small Generating Facilities~~ DER located within 2.5 electrical circuit miles of a substation and on a mainline (as defined in the table below) are eligible for the Fast Track Process under the higher thresholds according to the table below. In addition~~to the size threshold~~, the Interconnection Customer's proposed DER ~~Small Generating Facility~~ must meet the codes, standards, and certification requirements of Attachments 3 and 4 of these procedures, or the ~~Transmission~~ Distribution Provider has to have reviewed the design or tested the proposed DER ~~Small Generating Facility~~ and be ~~is~~ satisfied that it is safe to operate.

Fast Track Eligibility for Inverter-Based Systems		
Line Voltage	*Export Capacity of DER Eligible for Fast Track ~~Eligibility~~ Regardless of Location*	*Export Capacity of DER Eligible for Fast Track ~~Eligibility~~ on a Mainline and ≤ 2.5 Electrical Circuit Miles from Substation*
< 5 kV	*≤ 500 kW*	*≤ 500 kW*
≤ 5 kV and < 15 kV	*≤ 2 MW*	*≤ 3 MW*
≤ 15 kV and < 30 kV	*≤ 3 MW*	*≤ 4 MW*
≤ 30 kV and ≤ 69 kV	*≤ 4 MW*	*≤ 5 MW*

2.2.1 Screens

2.2.1.2 For interconnection of a proposed DER ~~Small Generating Facility~~ to a radial distribution circuit, the aggregated Export Capacity ~~generation~~, including the proposed DER ~~Small Generating Facility~~, on the circuit shall not exceed 15 % of the line section annual peak load as most recently measured at the substation. A line section is that portion of a ~~Transmission~~ Distribution Provider's electric system connected to a customer bounded by automatic sectionalizing devices or the end of the distribution line.

2.2.1.3 For interconnection of a proposed DER that can introduce Inadvertent Export, where the Nameplate Rating minus the Export Capacity is greater than 250 kW, the following Inadvertent Export screen is required. With a power change equal to the Nameplate Rating minus the Export Capacity, the change in voltage at the point on the medium voltage (primary) level nearest the Point of Interconnection does not exceed 3%. Voltage change will be estimated applying the following formula:

Formula	$\frac{(R_{SOURCE} \times \Delta \boldsymbol{P}) - (X_{SOURCE} \times \Delta \boldsymbol{Q})}{V^2}$
Where: $\Delta \boldsymbol{P}$ = (DER apparent power Nameplate Rating – Export Capacity) × PF, $\Delta \boldsymbol{Q}$ = (DER apparent power Nameplate Rating – Export Capacity) × $\sqrt{(\mathbf{1} - \boldsymbol{PF^2})}$, R_{SOURCE} is the grid resistance, X_{SOURCE} is the grid reactance, V is the grid voltage, PF is the power factor	

2.2.1.~~3~~4 For interconnection of a proposed DER~~Small Generating Facility~~ to the load side of spot network protectors, the proposed DER ~~Small Generating Facility~~ must utilize an inverter-based equipment package and the proposed DER's Nameplate Rating, together with the aggregated Nameplate Rating of other inverter-based generation, shall not exceed the smaller of 5 % of a spot network's maximum load or 50 kW.[54]

2.2.1.~~4~~5 The fault current of the proposed DER ~~Small Generating Facility~~, in aggregation with the fault current of other DER ~~generation~~ on the distribution circuit, shall not contribute more than 10 % to the distribution circuit's maximum fault current at the point on the high voltage (primary) level nearest the proposed point of change of ownership.

2.2.1.~~5~~6 The fault current of the proposed DER ~~Small Generating Facility~~, in aggregate with fault current of other ~~generation~~ DER on the distribution circuit, shall not cause any distribution protective devices and equipment (including, but not limited to, substation breakers, fuse cutouts, and line reclosers), or Interconnection Customer equipment on the system to exceed 87.5 % of the short circuit interrupting capability; nor shall the interconnection be proposed for a circuit that already exceeds 87.5 % of the short circuit interrupting capability.

2.2.1.~~7~~8 If the proposed DER ~~Small Generating Facility~~ is to be interconnected on a single-phase shared secondary, the aggregate Export Capacity ~~generation capacity~~ on the shared secondary, including the proposed DER ~~Small Generating Facility~~, shall not exceed:

-Some states use "20 kW"

-Some states use "65 % of the transformer nameplate power rating"

2.2.1.~~9~~10 The Nameplate Rating of the DER ~~Small Generating Facility~~, in aggregate with the Nameplate Rating of other ~~generation~~ DER interconnected to the transmission side of a substation transformer feeding the circuit where the ~~Small Generating Facility~~ DER proposes to interconnect shall not exceed 10 MW in an area where there are known, or posted, transient stability limitations to generating units located in the general electrical vicinity (e.g., three or four transmission busses from the Point of Interconnection).

[54] A spot network is a type of distribution system found within modern commercial buildings to provide high reliability of service to a single customer. *See* Donald Fink and H. Wayne Beaty, *Standard Handbook for Electrical Engineers, 11th edition*, McGraw Hill Book Company (1978).

2.4 Supplemental Review

2.4.4.1 Minimum Load Screen: Where 12 months of line section minimum load data (including onsite load but not station service load served by the proposed DER ~~Small Generating Facility)~~ are available, can be calculated, can be estimated from existing data, or determined from a power flow model, the aggregate Export Capacity ~~Generating Facility capacity~~ on the line section is less than 100% of the minimum load for all line sections bounded by automatic sectionalizing devices upstream of the proposed DER~~Small Generating Facility~~. If minimum load data is not available, or cannot be calculated, estimated or determined, the ~~Transmission~~ Distribution Provider shall include the reason(s) that it is unable to calculate, estimate or determine minimum load in its supplemental review results notification under section 2.4.4.

2.4.4.1.1 The type of generation used by the proposed ~~Small Generating Facility~~ DER will be taken into account when calculating, estimating, or determining circuit or line section minimum load relevant for the application of screen 2.4.4.1. Solar photovoltaic (PV) generation systems with no battery storage use daytime minimum load (i.e. 10 a.m. to 4 p.m. for fixed panel systems and 8 a.m. to 6 p.m. for PV systems utilizing tracking systems), while all other generation uses absolute minimum load.

2.4.4.1.2 When this screen is being applied to a ~~Small Generating Facility~~ DER that serves some station service load, only the net injection into the ~~Transmission Provider's~~ electric system will be considered as part of the aggregate generation.

2.4.4.1.3 ~~Transmission~~ Distribution Provider will not consider as part of the aggregate Export Capacity ~~generation~~ for purposes of this screen ~~generating facility capacity~~ DER Export Capacity known to be already reflected in the minimum load data.

2.4.4.2 Voltage and Power Quality Screen: In aggregate with existing generation on the line section: (1) the voltage regulation on the line section can be maintained in compliance with relevant requirements under all system conditions; (2) the voltage fluctuation is within acceptable limits as defined by Institute of Electrical and Electronics Engineers (IEEE) Standard 1453, or utility practice similar to IEEE Standard 1453; and (3) the harmonic levels meet IEEE Standard 519 limits. If the DER limits export pursuant to Section [4.10], the Export

Capacity must be included in any analysis including power flow simulations.

2.4.4.3 *Safety and Reliability Screen: The location of the proposed ~~Small Generating Facility~~ DER and the aggregate Export Capacity ~~generation capacity~~ on the line section do not create impacts to safety or reliability that cannot be adequately addressed without application of the Study Process. If the DER limits export pursuant to Section 4.10, the Export Capacity must be included in any analysis including power flow simulations, except when assessing fault current contribution. To assess fault current contribution, the analysis must use the rated fault current; for example, the Customer may provide manufacturer test data (pursuant to the fault current test described in IEEE 1547.1-2020 clause 5.18) showing that the fault current is independent of the Nameplate Rating. The ~~Transmission~~ Distribution Provider shall give due consideration to the following and other factors in determining potential impacts to safety and reliability in applying this screen.*

2.4.4.3.1 *Whether the line section has significant minimum loading levels dominated by a small number of customers (e.g., several large commercial customers).*

2.4.4.3.2 *Whether the loading along the line section is uniform or even.*

2.4.4.3.3 *Whether the proposed ~~Small Generating Facility~~ DER is located in close proximity to the substation (i.e., less than 2.5 electrical circuit miles), and whether the line section from the substation to the Point of Interconnection is a Mainline rated for normal and emergency ampacity.*

2.4.4.3.4 *Whether the proposed DER ~~Small Generating Facility~~ incorporates a time delay function to prevent reconnection of the ~~generator~~ DER to the system until system voltage and frequency are within normal limits for a prescribed time.*

2.4.4.3.5 *Whether operational flexibility is reduced by the proposed DER~~Small Generating Facility~~, such that transfer of the line section(s) of the DER ~~Small Generating Facility~~ to a neighboring distribution circuit/substation may trigger overloads or voltage issues.*

2.4.4.3.6 *Whether the proposed DER~~Small Generating Facility~~ employs equipment or systems certified by a recognized standards organization to address technical issues such as,*

but not limited to, islanding, reverse power flow, or voltage quality.

a. System Impact Study

3.4.1 System Impact Study

A system impact study shall identify and detail the electric system impacts that would result if the proposed ~~Small Generating Facility~~ DER were interconnected without project modifications or electric system modifications, focusing on the adverse system impacts identified in the feasibility study, or to study potential impacts, including but not limited to those identified in the scoping meeting. A system impact study shall evaluate the impact of the proposed interconnection on the reliability of the electric system.

The system impact study must take into account the proposed DER's design and operating characteristics, including but not limited to the applicant's proposed Operating Profile (where verifiable), and study the project according to how the project is proposed to be operated. If the DER limits export pursuant to Section [4.10], the system impact study must use Export Capacity instead of the Nameplate Rating, except when assessing fault current contribution. To assess fault current contribution, the system impact study must use the rated fault current; for example, the Customer may provide manufacturer test data (pursuant to the fault current test described in IEEE 1547.1-2020 clause 5.18) showing that the fault current is independent of the Nameplate Rating.

b. System Impact Study Agreement

5.0 *A system impact study shall consist of a short circuit analysis, a stability analysis, a power flow analysis, voltage drop and flicker studies, protection and set point coordination studies, and grounding reviews, as necessary. A system impact study shall state the assumptions upon which it is based, state the results of the analyses, and provide the requirement or potential impediments to providing the requested interconnection service, including a preliminary indication of the cost and length of time that would be necessary to correct any problems identified in those analyses and implement the interconnection. The system impact study shall take into account the proposed DER's design and operating characteristics, including but not limited to the applicant's proposed Operating Profile (where verifiable), and study the project according to how the project is proposed to be operated. If the DER limits export pursuant to Section [4.10], the system impact study shall use Export Capacity instead of the Nameplate Rating, except when assessing fault current contribution. To assess fault current contribution, the system impact study shall use the rated fault current; for example, the Customer may provide manufacturer test data (pursuant to the fault current test described in IEEE 1547.1-2020 clause 5.18) showing that the fault current is independent of the Nameplate Rating. A system impact study shall provide a list of facilities that are required as a result of the Interconnection Request and non-binding good faith estimates of cost responsibility and time to construct.*

c. Feasibility Study Agreement

4.0 The feasibility study shall be based on the technical information provided by the Interconnection Customer in the Interconnection Request, including the proposed DER's design characteristics, operating characteristics, and Operating Profile (where verifiable), as may be modified as the result of the scoping meeting. If the DER limits export pursuant to Section [4.10], the feasibility study must use Export Capacity instead of the Nameplate Rating, except when assessing fault current contribution. To assess fault current contribution, the system impact study must use the rated fault current; for example, the Customer may provide manufacturer test data (pursuant to the fault current test described in IEEE 1547.1-2020 clause 5.18) showing that the fault current is independent of the Nameplate Rating. The ~~Transmission~~Distribution Provider reserves the right to request additional technical information from the Interconnection Customer as may reasonably become necessary consistent with Good Utility Practice during the course of the feasibility study and as designated in accordance with the standard Small Generator Interconnection Procedures. If the Interconnection Customer modifies its Interconnection Request, the time to complete the feasibility study may be extended by agreement of the Parties.