Hydro Québec

Guideline
Standard

Title of guideline	Guideline number	Effective date YYYY-MM-DD
Technical requirements for distributed generation interconnection to the Hydro-Québec distribution system	**E.12-01**	**2025-11-17**

Scope

Group(s) affected
Exploitation et infrastructures [operations and infrastructure] **Planification énergétique et expérience client [energy planning and customer experience]**

Processes affected
Connecting a power producer to the Hydro-Québec distribution system **Connecting a Self-generation customer to the Hydro-Québec distribution system**

Details on scope
This standard defines the minimum requirements and technical specifications for distributed generation connected to the Hydro-Québec low-voltage (LV) and medium-voltage (MV) distribution system. **It is intended for Self-generation customers and power producers.**

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Definitions

Self-generation customer	Customer that generates electricity in a facility that it owns and operates to meet all or part of its needs.
backup power supply	Power supply to be used only in the event of a temporary shutdown of the Hydro-Québec system and capable of supplying all essential loads.
low voltage	Connection voltage of 120/240 volts single-phase or 347/600 volts three-phase.
blocking	In the context of operating an inverter-based resource, blocking refers to when an inverter discontinues current injection while remaining in service. The inverter must be able to resume electricity generation as soon as the voltage and frequency are once again within the defined operating ranges.
generating station	A set of installations forming a generating plant that produces electrical power by converting other forms of energy. The primary function of a generating station is to generate electrical energy
communicating meter	A meter with two-way communication that can receive and send information via radio frequencies or a telephone link.
tripping	In the context of operating an inverter-based resource, tripping refers to when an inverter discontinues current injection and enters shutdown mode. This mode prevents the inverter from being reconnected until all startup requirements are met.
microgrid interconnection device	Device that enables a group of electrical components found within a given perimeter and having one or more sources of backup power supply to disconnect from Hydro-Québec's power system and reconnect to it.
generating unit	A unit that produces electricity, usually comprised of a synchronous turbine-generator set (synchronous generator) or an asynchronous turbine-generator set (asynchronous generator) or, in the case of generating stations using inverter-based resources (IBRs), the set formed by each individual energy source and its associated inverter.
islanding	The separation of a power system into subsystems, including load and generation or generation and Hydro-Québec facilities (with or without load), that occurs following a disturbance or switching operation.
engineer	A person who holds a licence to practise engineering issued by the Ordre des ingénieurs du Québec, in accordance with the *Engineering Act* (CQLR, c. I-9).
electricity generating facility	Facility designed to generate electricity in the Hydro-Québec system. Includes generation equipment, auxiliary services, and instrumentation and protection equipment.
medium voltage	Nominal phase-to-phase voltage of more than 750 volts but less than 44,000 volts.
inverter	Device or facility that converts direct current to alternating current.
multimode inverter	Inverter that combines the capabilities of an inverter connected to the system and a standalone inverter. It can function in either system-synchronized mode or island mode.

continuous operation	State in which an electricity generating facility is connected to the power system and injecting current into it, or available to do so, as long as the voltage and frequency are within the range of normal or marginal operating conditions.
ride-through	The ability of an electricity generating facility to withstand voltage or frequency variation events within defined ranges and to continue to generate electricity as intended.
distribution substation	A large-scale indoor or outdoor facility located at the confluence of several power lines and housing equipment required to transform high voltage to medium voltage.
power producer	A person, company, corporation or organization, including Hydro-Québec, that owns or leases a facility whose primary function is to generate electricity.
EGF owner	A person, company, corporation or organization, including Hydro-Québec, that owns or leases an electricity generating facility.
out-of-sync reclosing	Automatic closure of a circuit breaker or recloser between two energized portions of the system that do not share the same electrical characteristics (voltage, frequency and phase).
remaining in operation	In the context of operating an inverter-based resource, remaining in operation refers to when an inverter continues to inject current into the power system, as it is expected to do, even while riding through a disturbance.
inverter-based resource	Any primary or storage-system-based source of energy that is capable of providing active power and that uses DC-AC converter technology to connect to the grid (e.g. wind energy, solar energy, battery-stored energy, etc.).

Acronyms and abbreviations

LV	Low voltage
AC	Alternating current
DC	Direct current
DCC	Distribution control centre [Centre d’exploitation de distribution]
MID	Microgrid interconnection device
PF	Power factor
EGF	Electricity generating facility
MV	Medium voltage
OIQ	Ordre des ingénieurs du Québec
RMS	Root-mean-square voltage
IBR	Inverter-based resource

DERMS	Distributed energy resource management system
UTAPP	Private producers' remote control and acquisition unit (Unité de télécommande et d'acquisition des producteurs privés)
XFO	Transformer
EGC	Equipment Grounding Conductor

1 Purpose and application

This standard defines the minimum requirements and technical specifications for the connection of distributed generation to the Hydro-Québec low-voltage (LV) and medium-voltage (MV) distribution system. It also applies when an existing electricity generating facility (EGF) undergoes a physical change, software change or refurbishment.

It replaces Standard E.12-05 *Exigences relatives au raccordement de la production décentralisée au réseau basse tension d'Hydro-Québec* [requirements for the interconnection of distributed generation to the Hydro-Québec low-voltage system] and Standard E.12-06 *Exigences relatives au raccordement de la production décentralisée sans injection de puissance au réseau de distribution d'Hydro-Québec* [requirements for the interconnection of distributed generation without injection of power to the Hydro-Québec distribution system] These two standards are therefore withdrawn.

This standard applies to any facility used to generate electricity in the Hydro-Québec distribution system or at a customer's facility connected to the Hydro-Québec distribution system, regardless of the method used to generate electricity or the load at the customer facility, if applicable. It applies to generating stations and Self-generation customer facilities with or without injection of power into the Hydro-Québec system. It also applies to stationary and mobile storage systems, as well as to facilities comprising electric vehicles capable of producing electricity that are connected to the Hydro-Québec distribution system.

EGFs connected to the LV system made up solely of certified inverter-based resources (IBRs), having a total cumulative power of 100 kW or less, and not having a transformer between the inverter and the customer Point of Connection may meet the simplified requirements set out in Standard E.12-07.

Hydro-Québec requirements for the interconnection of EGFs used as backup power sources, but not equipped with a transfer switch and mechanical interlock system that make it impossible to couple backup generators with the power system (open transition), can be found in Standard E.12-08.

To simplify the text, the term inverter is used in the singular throughout the document. However, the standard's requirements apply to any facility composed of either one or several inverters. The singular should be substituted with the plural, as applicable.

Given the various means of generation, modes of interconnection and potential system constraints, Hydro-Québec may define certain specific requirements at the time each case is reviewed.

Hydro-Québec's off-grid systems are permanently disconnected from Hydro-Québec main electrical system. Their electricity supply is generated locally. Consequently, although this standard must be respected when connecting an EGF to a Hydro-Québec off-grid system, specific requirements must also be issued for each project.

2 Scope

This standard is intended for Self-generation customers and for power producers whose EGF is connected to the Hydro-Québec distribution system. Compliance is mandatory.

It is also intended for Hydro-Québec employees responsible for integrating distributed generation into the distribution system.

3 Related guidelines

This standard is one of a series of documents governing the technical requirements for the interconnection of electricity generating facilities to the Hydro-Québec distribution system. These documents include the following:

A.5-09, Application d'un transformateur de mise à la terre dans une IPE équipée de SERMO et raccordée au réseau de distribution d'Hydro-Québec [application of a grounding transformer in an EGF using IBRs connected to the Hydro-Québec's distribution system]

A.5-10, Application de la norme E.12-01 au raccordement d'une IPE triphasée [application of Standard E.12-01 to the connection of a three-phase EGF connection]

C.22-03, Exigences techniques relatives au raccordement des charges fluctuantes au réseau de distribution d'Hydro-Québec [technical requirements for connecting fluctuating loads to the Hydro-Québec distribution system]

C.25-01, Exigences techniques relatives à l'émission d'harmoniques par les installations de clients raccordés au réseau de distribution d'Hydro-Québec [technical requirements for harmonic emissions by customer facilities connected to the Hydro-Québec distribution system]

C.42-01, Modalités d'exploitation entre Hydro-Québec et l'exploitant d'une installation de production d'électricité raccordée au réseau de distribution [operating terms and conditions between Hydro-Québec and the operator of an electricity generating facility connected to the distribution system]

D.24-20 *Critères de vérification des dispositifs d'isolement de source d'énergie* [criteria for checking isolating devices]

D-2022-088, Exigences techniques de raccordement de centrales au réseau de transport d'Hydro-Québec [technical requirements for the interconnection of generating stations to the Hydro-Québec transmission system]

D-5580, Hydro-Québec Work Safety Code – Distribution chapter

E.12-02, Planification du réseau de distribution d'Hydro-Québec pour l'intégration de la production décentralisée [Hydro-Québec distribution system planning for the interconnection of distributed generation] (guideline available to Hydro-Québec employees only)

E.12-03, Maintenance des équipements de protection des installations de production décentralisée se raccordant au réseau moyenne tension d'Hydro-Québec [protection equipment maintenance for distributed generating facilities connected to the Hydro-Québec medium-voltage system]

E.12-05, Exigences relatives au raccordement de la production décentralisée au réseau basse tension d'Hydro-Québec [requirements for the interconnection of distributed generation to the Hydro-Québec low-voltage system] (this requirement has been withdrawn and replaced by E.12-01)

E.12-06, Exigences relatives au raccordement de la production décentralisée sans injection de puissance au réseau de distribution d'Hydro-Québec [requirements for the interconnection of distributed generation without injection of power to the Hydro-Québec distribution system] (this guideline has been withdrawn and replaced by E.12-01)

E.12-07, Exigences relatives au raccordement de la production décentralisée de 100 kW et moins utilisant des onduleurs certifiés au réseau de distribution basse tension d'Hydro-Québec [requirements for the interconnection of distributed generation of 100 kW or less using certified inverters to the Hydro-Québec low-voltage distribution system]

E.12-08, Exigences relatives au raccordement de groupes de production de secours au réseau de distribution d'Hydro-Québec à l'aide d'un système de commutation sans coupure [requirements for the interconnection of backup generators to the Hydro-Québec distribution system using a closed transition system]

E.12-09, Exigences relatives à la qualification des équipements de protection utilisés pour le raccordement de la production décentralisée sur le réseau de distribution d'Hydro-Québec [qualification requirements for protection equipment used for the connection of distributed generation to the Hydro-Québec distribution system]

E.12-12, Exigences pour l'installation et le raccordement de l'unité de télécommande et de télésignalisation des installations des producteurs indépendants et des autoproducteurs raccordés au réseau moyenne tension d'Hydro-Québec [requirements for installing and connecting remote control and remote indication units at independent producer and self-generation facilities connected to the Hydro-Québec medium-voltage system]

E.21-10, Service d'électricité en basse tension [low-voltage electricity service]

E.21-11, Service d'électricité en basse tension à partir des postes distributeurs [low-voltage electricity service from distribution substations]

E.21-12, Service d'électricité en moyenne tension [medium-voltage electricity service]

F.22-01, Mesurage de l'électricité en moyenne et haute tension [electricity metering for medium- and high-voltage facilities]

F.22-05, Mesurage de la production décentralisée de 250 kW et plus raccordée au réseau basse tension d'Hydro-Québec [metering of distributed generation of 250 kW or more connected to the Hydro-Québec low-voltage system]

ISBN 978-2-550-97120-7, Electricity Rates Effective April 1, 2024

ISBN 978-2-550-88671-6, Conditions of Service

0332-18-006-B *Raccordement des transformateurs pour les clients moyenne tension (CMT) et les installations de production d'électricité (IPE)* [transformer connections for medium-voltage customers (MVC) and electricity generating facilities (EGF) (guideline available to Hydro-Québec employees only)

4 Distribution system characteristics

4.1 General information

The connection of an EGF to the LV distribution system may be single-phase (120/240 volts) or three-phase (347/600 volts).

The connection of an EGF to the MV distribution system may be single-phase or three-phase for customer-generators. In this case, the limitations in section 5.2 apply. A medium-voltage generating station connection must be three-phase.

The connection of an EGF to the MV distribution system is usually carried out at a nominal voltage of 25 kV (14.4/24.94 kV). When the connection is made at a different voltage level, the facilities must be designed so as to be connected at the voltage level existing at the time of the connection and also at 25 kV, unless Hydro-Québec has sent a written exemption to the power producer.

When the MV distribution system voltage isn't 25 kV, Hydro-Québec informs the power producer of the system's specific requirements.

An EGF connected to the distribution system must be designed to be able to be connected at one of the voltages presented in Table 1, in accordance with Table 2 and section 8 of Standard CSA C235-R2019, *Preferred voltage levels for AC systems up to 50,000 V.*

Table 1: Nominal voltage range at the Point of Connection

Nominal voltage	Voltage variation limits at the connection point			
	Marginal operating conditions			
		Normal operating conditions		
Single-phase LV system 120/240 V	106/212 V	110/220 V	125/250 V	127/254 V
Three-phase LV system 347/600 V	306/530 V	318/550 V	360/625 V	367/635 V
MV system 14 400/24 940 V	0.94 p.u. 13 536/23 444 V	0.958 p.u. 13 795/23 893 V	1.042 p.u. 15 005/25 987 V	1.06 p.u. 15 264/26 436 V

Under normal operating conditions, the frequency of Hydro-Québec's integrated power system is maintained between 59.4 Hz and 60.6 Hz as set out in the document *Caractéristiques de la tension fournie par les réseaux moyenne et basse tension d'Hydro-Québec* [characteristics of the voltage supplied by the Hydro-Québec medium- and low-voltage systems].

4.2 Neutral grounding system

The Hydro-Québec distribution system has a neutral grounding system that is effectively grounded and meets the following two conditions:

$$\frac{X_0}{X_1} \leq 3 \text{ and } \frac{R_0}{X_1} < 1$$

X_0: Zero-sequence reactance
X_1: Positive sequence reactance
R_0: Zero-sequence resistance

Equation 1: Conditions of an effectively grounded neutral system

4.3 Overhead LV system

The overhead LV system consists of triplex conductors (two insulated and one bare) in the case of the 120/240-V system, and of quadruplex conductors (three insulated and one bare) in the case of the 347/600-V system. It extends to the Point of Connection of the last customer to be connected. For certain large-power customers, the Point of Connection is on the distribution transformer.

4.4 Underground LV system

The underground LV system is comprised for 120/240 V of three insulated conductors (one neutral and two phase conductors) and for 347/600 V of four insulated conductors (one neutral and three phase conductors).

4.5 Overhead MV system

Hydro-Québec's medium-voltage distribution system consists primarily of overhead lines. The three-phase portion of these lines generally consists of three phase conductors and one neutral conductor.

4.6 Underground MV system

Hydro-Québec's medium-voltage distribution system consists partially of underground lines. The three-phase portion of these lines generally consists of three single-phase stranded cables with a concentric neutral.

4.7 Point of Connection

The Point of Connection (PoC) acts as a dividing line between the Hydro-Québec system and that of the EGF.

4.7.1 Self-generation customer or generating station connected to the LV system

Under this standard, the Point of Connection for an LV installation of 600 A or less[1] is as shown in Standard E.21-10 *Service d'électricité en basse tension* [low-voltage electrical service], commonly known as the "Blue Book," replacing the term "customer" with "power producer" or "Self-generation customer."

For an LV installation greater than 600A, the Point of Connection is as shown in Standard E.21-11, *Service d'électricité en basse tension à partir des postes distributeurs* [low-voltage electricity service from distribution substations], commonly known as the "Green Book," replacing the term "customer" with "power producer" or "Self-generation customer."

In the case where an EGF is owned by an LV customer connected as per Standard E.21-11, *Service d'électricité en basse tension à partir des postes distributeurs* [low-voltage electricity service from distribution substations], and an electricity supply contract requires installation of a meter for the EGF that is separate from the one used by the customer, the second meter shall be connected at the customer Point of Connection (Appendix B Figure 2).

[1] A 600 A EGF installation at 347/600 V corresponds to rated capacity of 593 kW, considering the requirement of a design power factor of 0.95 (section 7.2.1).

4.7.2 Generating station connected to the overhead MV system

The Point of Connection is located where the generating station connection conductors are connected to the end-of-line insulators of the support structure on which Hydro-Québec has installed the switch upstream of the generating station as shown in Figure 13 of Appendix B.

The location of the Point of Connection varies from one system configuration to the next, but must be accessible at all times by Hydro-Québec employees without requiring a third party.

4.7.3 Generating station connected to the underground MV system

The Point of Connection is located at the generating station cable potheads in the civil structure housing the switch installed by Hydro-Québec upstream of the generating station, as shown in Figure 14 of Appendix B.

The location of the Point of Connection varies from one system configuration to the next, but the Point of Connection must be in a location that can be accessed at all times by Hydro-Québec employees without requiring a third party.

4.7.4 Generating station connected to a customer's existing MV substation

The Point of Connection for the existing customer is maintained. The generating station must be connected to the existing customer MV substation upstream of the existing customer circuit breaker used to protect Hydro-Québec metering as shown in Figure 15 of Appendix B.

4.7.5 Self-generation customer connected to the MV system

The Point of Connection is as illustrated in Standard E.21-12 Service d'électricité en moyenne tension [medium-voltage electrical service], commonly referred to as the "Red Book," replacing the term "customer" with "Self-generation customer."

5 General requirements

The integration of an electricity generating facility (EGF) into the Hydro-Québec distribution system must not under any circumstance:

- compromise the safety of Hydro-Québec employees or the public
- substantially alter the quality of the voltage delivered to Hydro-Québec customers
- substantially alter service continuity for Hydro-Québec customers

5.1 Total maximum rated capacity

The total maximum rated capacity for an EGF connected to the LV system is 5 MW for a three-phase facility. This maximum capacity corresponds to the total rated capacity of all EGF generating units. Sometimes a connection to the LV system may not be acceptable. In this case, the Hydro-Québec representative will inform the EGF owner, and alternative solutions (such as a medium- or low-voltage connection via a dedicated line) may be examined at the owner's request.

The maximum total rated capacity of an EGF connected to the Hydro-Québec LV system in accordance with Standard E.21-10 *Service d'électricité en basse tension* [low-voltage electrical service], commonly referred to as the "blue book," and not equipped with minimum load protection (section 9.1.3) must be less than 250 kW.[2] Above this threshold, the EGF must:

- be connected to the Hydro-Québec LV system in accordance with Standard *E.21-11 Service d'électricité en basse tension à partir des postes distributeurs* [low-voltage electrical service from distribution substations] commonly referred to as the "Green Book" or;
- be equipped with protection to limit injection of power (section 9.1.4).

The maximum total rated capacity for an EGF connected to the MV system at a voltage of 25 kV is 12 MW for a three-phase facility.[3]

In the case of an EGF connected at the premises of a Self-generation customer, the connected load within the customer portion of the facility does not increase the allowable maximum total rated capacity.

In the case of an EGF with a single-phase Point of Connection to the Hydro-Québec system, it is recommended to limit the maximum total rated capacity to 40 kW. Additional capacity may be connected by special request subject to an System Impact Study (section 5.8) by Hydro-Québec.

The power generated at each of the phases must be balanced when the Point of Connection of an EGF to the Hydro-Québec system is three-phase.

The maximum power from an EGF that can be carried by a distribution line may be limited to a lower level by the following factors:

- Voltage profile on the line following interconnection of the EGF (section 5.8)
- Capacity of Hydro-Québec system components
- Stability of EGF generating units during disturbances or load variations on the Hydro-Québec system
- Voltage fluctuations during EGF startup or shutdown
- Protection coordination and service quality
- Characteristics of the distribution substation and transmission system supplying the distribution feeder

During the System Impact Study (section 5.8), the Hydro-Québec representative will assess the connection request and determine whether the EGF exceeds the maximum power that can be connected to the distribution system in question.

5.2 Additional requirements for EGFs with a capacity of 250 kW or greater

The following additional requirements apply specifically to EGFs of 250 kW and over:

- Generating units must be three-phase.

[2] This is to allow Hydro-Québec to install a disconnect point (section 5.4) that can be used to isolate the customer without interrupting the power supply to other customers.

[3] Standard E.21-12 establishes a maximum load of 12 MVA for customers that can be connected to the MV system. The same is true for EGFs. However, capacity could reach 24 MW under the best conditions, for example if the type of line (overhead or underground), the conductor capacity and the type of distribution substation line feeder allowing it.

- The EGF must comply with IEC 62786-1 *Distributed energy resources connection with the grid – Part 1: General requirements*. The values of the numeric variables required under the standard are listed in Appendix H:.
- The EGF is subject to extended voltage and frequency variation immunity thresholds (sections 6.4 and 6.7).
- It must allow for configuration of maximum ramp rates for power ramp-ups and ramp-downs (section 7.2.2).
- Installation of a private producers remote control and acquisition unit (UTAPP) will be required at facilities with the capacity to inject 250 kW or more into the Hydro-Québec system (section 10.5).
- Numerical models for modelling the EGF in the Hydro-Québec system must be submitted (section 5.11).

EGFs of 1.0 MW and over are also subject to the *Exigences techniques de raccordement de centrales au réseau de transport d'Hydro-Québec* [technical requirements for the interconnection of generating stations to the Hydro-Québec transmission system].

In light of the greater impact that EGFs of 250 kW or more have on the Hydro-Québec system, these requirements are intended to ensure the reliability of these facilities in order to maintain voltage quality and service continuity to customers and ensure the safety of Hydro-Québec employees and the public.

5.3 Neutral system

The type of connection preferred by Hydro-Québec is one where the characteristics of the EGF equipment are such that the neutral system is effectively grounded at the Point of Connection and along the entire interconnection line under both normal operating conditions and fault conditions.

The Facilities Study (section 5.9) must therefore take into account the maintenance of a neutral system that is effectively grounded at the EGF Point of Connection and along the entire MV distribution line in the following three situations:

- When the EGF is not producing electricity and its auxiliary services are powered solely by the Hydro-Québec system (under the responsibility of Hydro-Québec)
- When the EGF is generating electricity and supplying the Hydro-Québec system in the presence of distribution substation power (under the responsibility of the engineer appointed by the EGF owner)
- When the EGF is generating electricity and supplying the Hydro-Québec system in the absence of distribution substation power, i.e., the EGF is temporarily supplying the Hydro-Québec line in islanded mode, following the opening of a device on the Hydro-Québec line prior to the EGF main circuit breaker being opened (under the responsibility of the engineer appointed by the EGF owner)

For this purpose, a zero-sequence current source may be required inside the EGF[4] (section 8.3). If this is the case, the source must be sized in accordance with Equation 2 in order to maintain an effectively grounded neutral system and avoid masking the circuit breaker protection on the Hydro-Québec line feeder.

[4] Refer to IEEE C62.92.1 *Guide for the Application of Neutral Grounding in Electrical Utility Systems--Part I: Introduction*, IEEE C62.92.2 *Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part II—Synchronous Generator Systems* and IEEE C62.92.4 *Guide for the Application of Neutral Grounding in Electrical Utility Systems--Part IV: Distribution* for the calculation methods to be used.

$$2 \leq \frac{X_0}{X_1} \leq 3 \; and \; \frac{R_0}{X_1} < 1$$

X_0: Zero-sequence reactance
X_1: Positive sequence reactance
R_0: Zero-sequence resistance

Equation 2: Conditions for an effectively grounded neutral system in an EGF

5.3.1 IBR

In the case of an EGF with IBR, the electrical characteristics of the inverters do not allow for use of the coefficients in Equation 2. In this case, a grounding coefficient ($Coef_{Ground}$) less than or equal to 0.8 must be respected. The grounding coefficient is defined in Equation 3.[5]

$$Coef_{Ground} \leq 0.8 \; and \; Coef_{Ground} = \frac{V_{Line-to-ground}}{V_{Line-to-line}}$$

$V_{Line-to-ground}$: Maximum line-to-ground RMS voltage at the fundamental frequency, on a healthy phase, at a given location, during a phase-to-ground fault
$V_{Line-to-line}$: Line-to-line RMS voltage at the fundamental frequency, in the absence of a short circuit

Equation 3: Conditions of an effectively grounded neutral regime in an EGF

Calculating the grounding coefficient of an EGF using IBRs is a complex task. It requires precise knowledge of the negative- and zero-sequence contributions of the inverters, I.e., the behaviour of the inverters when subject to negative- and zero-sequence voltage imbalances.[6]

Unfortunately, these values are often unavailable from the manufacturers. For this reason, Hydro-Québec has taken a pragmatic approach to this problem:

- For an EGF using an IBR with a capacity of less than 250 kW, the inverter must have a phase-to-neutral and phase-to-phase surge detection circuit compliant with Standard IEEE 1547-2018, section 7.4 *Limitation of overvoltage contribution* (section 7.3.2). This ensures $Coef_{Ground} \leq 0.8$ without needing to know the negative-sequence and zero-sequence impedance of the inverters.
- For EGF with IBRs of 250 kW and over, the inverter must comply with IEC 62786-1. This ensures that the negative-sequence contribution of the inverter is predictable. The zero-sequence contribution of the inverter will be estimated at zero. A zero-sequence current source (section 8.3) can then be used when required to maintain a $Coef_{Ground} \leq 0.8$.

[5] Refer to IEEE C62.92.6 *Guide for Application of Neutral Grounding in Electrical Utility Systems, Part VI—Systems Supplied by Current-Regulated Sources* for the calculation methods to be used.
[6] Inverters covered by this standard should not have a zero-sequence contribution, particularly since they are intended for use in grid-connection mode.

If an inverter used in an EGF does not meet the above characteristics, for example an inverter used in an industrial process (section 8.13.3), the engineer performing the grounding coefficient calculation must either measure the negative-sequence contribution of the inverter or assume that the contribution is zero. In this situation, negative-sequence impedance is required in the EGF, e.g., load in the case of an EGF installed at a Self-generation customer's premises (section 5.3.2), failing which the grounding coefficient cannot be equal to or less than 0.8 and the connection will be refused.

5.3.2 Self-generation customer using IBR

In the case of an EGF installed at a Self-generation customer's premises, the flowchart in Appendix D summarizes the criteria that must be taken into account when assessing the temporary overvoltage risk associated with connecting an EGF with IBR.[7] The criteria are as follows:

1. If the minimum load[8] at the customer facility is equal to or greater than 1.5 times the total power of the EGF, the load will be sufficient to override production in the event of a fault or load rejection. Therefore, there is no risk of temporary overvoltage in case of a phase-to-ground fault or a load rejection.[9]
2. If the minimum load at the customer's facility is equal to or greater than one (1) times the total power of the EGF and at least one-third (1/3) of the load is phase-to-neutral at the Point of Connection to the Hydro-Québec system, phase-to-neutral loads will allow enough negative-sequence and zero-sequence current to flow to override production in the event of a fault or load rejection. Therefore, there is no risk of temporary overvoltage in the event of a phase-to-ground fault or load rejection.
3. If the IBR inverter has a surge detection function in the event of a phase-to-ground fault or load rejection,[10] the inverter must stop injecting current in less than 17ms when the phase-to-phase or phase-to-neutral nominal voltage exceeds 138% of the facility's nominal voltage. Thus, if the inverter has a neutral terminal, and zero-sequence continuity from the inverter to the Point of Connection has been ensured by choosing the appropriate type of power wiring (section 8.5) and power transformer (section 8.12), the inverter will stop injecting power in the event of an overvoltage on the Hydro-Québec system or inside the EGF, whether it is caused by a phase-to-ground fault or a load rejection. Therefore, there is no risk of temporary overvoltage in the event of a phase-to-ground fault or load rejection.
4. If, subsequent to a neutral grounding study[11] by the engineer representing the EGF's owner, a zero-sequence current source has been selected (section 8.3) to ensure a grounding coefficient of 0.8 or less, and negative-sequence impedance is present in the EGF, we can be sure that there is no risk of temporary overvoltage in the event of a phase-to-ground fault.[12] However, if the minimum

[7] Refer to EPRI report number 3002020130 *Effective Grounding for Inverter-Connected DER* for details.
[8] The minimum load must be inductive to avoid the risk of temporary overvoltage. It is also necessary to check whether a capacitor bank that is used, for example, to compensate for the power factor of the facility would remain in service at minimum load, which would effectively result in a capacitive load.
[9] In order to respect the 1.5 ratio, a customer may choose to implement a load and generation control system that limits power output when the load is insufficient.
[10] See section 9.1.5 Protection to limit contribution to overvoltage for more details.
[11] The engineer appointed by the EGF owner shall use the method outlined in section 7 of Standard IEEE Std C62.92.6 *Guide for Application of Neutral Grounding in Electrical Utility Systems, Part VI--Systems Supplied by Current-Regulated Sources*.
[12] EGFs using an inverter that complies with section 4.7.6 of Standard IEC 62786-1 *Additional reactive current requirements on generating plants* and to which a zero-sequence current source has been added will be capable of ensuring $Coef_{Ground} \leq 0.8$ and mitigating the risk of temporary overvoltage in the event of load loss if the facility is

load at the customer facility is less than 0.7 times the total power of the EGF, there is a risk of temporary overvoltage if the load is lost. Mitigation measures must be implemented, e.g., the use of an IEC 62786-1 certified inverter, failing which the connection request must be rejected.

5. If the EGF is equipped with a Type I remote trip link,[13] which ensures that the EGF main circuit breaker will always open before the distribution line feeder circuit breaker does, there is no risk of temporary overvoltage on the Hydro-Québec MV distribution line in the event of a phase-to-ground fault or load rejection. However, there is a risk of temporary overvoltage inside the customer facility. A surge impact analysis will need to be performed by the engineer representing the EGF owner, and mitigation measures implemented when required.

In the case of an EGF installed at a Self-generation customer's premises and connected to MV via a main transformer with (MV) - Y (LV) delta windings, given that the zero-sequence continuity from the inverter to the Point of Connection is broken by the delta winding of the main transformer, the easiest way to eliminate the risk of temporary overvoltage in the event of a phase-to-ground fault or load rejection is to ensure sufficient load at the customer facility. This corresponds to items one (1) and two (2) of the list above. If the load is insufficient:

- a Point of Connection for the EGF upstream of the main transformer Delta (MV) - Y (LV) should be considered; or
- the main transformer should be replaced by a transformer with windings that permit zero-sequence current (section 8.12.2); or
- a Type I remote trip link should be implemented.

5.4 Hydro-Québec disconnect point

In the case of generating stations and Self-generation customers with the capacity to inject 250 kW or more into the distribution system, Hydro-Québec installs a lockable medium-voltage disconnecting device to ensure safety when servicing or isolating the system. This device makes it possible to visually or positively verify the separation of the electrical isolation point.[14] This device is operated solely by Hydro-Québec personnel and is owned and maintained by Hydro-Québec.

5.5 Design

The EGF owner must comply with Hydro-Québec's Terms of Service in accordance with the *Hydro-Québec Act*. The EGF must be designed in such a way that it remains safe for Hydro-Québec personnel and the public under all circumstances.

EGF equipment and facilities must comply with the codes, standards and rules applicable in Québec and with good utility practices.

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properly designed and the inverter is configured for this purpose, due to the fact that a compliant inverter must modulate the current of each phase according to the phase voltage variations. This way, the inverter can not only produce negative-sequence current, but also act effectively in the event of load loss.

[13] A Type I remote trip link is a link that allows communication to be maintained during a short circuit on the distribution system. Loss of communication starts a timer that will trip the EGF circuit breaker if the loss of communication exceeds a predetermined time limit.

[14] For Hydro-Québec employees, the Standard D.24-20 *D.24-20 Critères de vérification des dispositifs d'isolement de source d'énergie* [criteria for checking isolating devices] provides more detail on this point.

The EGF must be designed so as not to cause the EGF to trip within no-trip zones (sections 6.4to 6.8) and to cause it to trip within must-trip zones (sections 9.8.3 and 9.8.4).

5.6 Municipal and government authorizations

Prior to the connection, the EGF owner must obtain all necessary municipal, provincial and federal approvals.

For example, a building permit may be required at the municipal level for the installation of solar panels or a wind turbine. A permit from the Québec Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs may be required for the installation of a small-power hydraulic turbine.

5.7 Information required by Hydro-Québec

The interconnection of an EGF to the distribution system may require modifications to existing Hydro-Québec facilities.

Information must therefore be provided to Hydro-Québec when requesting a connection in order to ensure that the technical requirements and connection conditions for the facility are met and to carry out the System Impact Study (section 5.8) that will help determine the modifications required to the grid and the conditions for connecting the EGF to the distribution system:

a) The form *Demande de raccordement d'équipements de production d'électricité au réseau d'Hydro-Québec* [request to connect generation equipment to the Hydro-Québec system] (APPENDIX A)

b) The single-line facility diagram (Appendix B) signed by an engineer

c) For IBRs, the certificate showing the inverter is compliant with Standard UL1741-SB, including the test results for UL1741-SB, section SB4.3.5.17

d) The certificate showing that the inverter is compliant with Standard IEEE 2030.5 / Sunspec Common Smart Inverter Profile (CSIP) version 2.1 or later

e) For IBRs of 250 kW or more, the certificate(s) showing inverter compliance with IEC 62786-1:2023 or later

5.8 System Impact Study

The purpose of the System Impact Study is to determine, from among several variants, an optimal technical, economic and environmental scenario for the interconnection of an EGF to the Hydro-Québec grid. This study is specific to a connection request for a particular new resource. The study provides a list of equipment and system modifications required, if any, for the interconnection of an EGF to the Hydro-Québec system.

The System Impact Study is carried out by Hydro-Québec using the information supplied with the connection request.[15]

[15] For Hydro-Québec employees, Standard E.12-02 *Planification du réseau de distribution d'Hydro-Québec pour l'intégration de la production décentralisée* [Hydro-Québec distribution system planning for the interconnection of distributed generation] provides more details on this point.

Hydro-Québec will conduct an System Impact Study in the following situations:

- Request to connect a generating station in accordance with section 1.28 of *Tarifs et conditions des services de transport d'Hydro-Québec Tarifs et conditions des services de transport d'Hydro-Québec* [Hydro-Québec transmission rates and conditions]. This requires a generating station System Impact Study.
- Request to connect a Self-generation customer's facility, for example, when system capacity is exceeded at the requested Point of Connection. This requires a self-generation System Impact Study.
- Request for modifications to a generating station or Self-generation customer's facility.

In the case of a Self-generation customer System Impact Study, the presence of a protection system to ensure minimum load (section 9.1.3) or limit injection of power (section 9.1.4) can help limit the EGF's impact on the Hydro-Québec system, thereby reducing the cost of connecting to the system and the time required to complete the work.

5.9 Facilities Study

The purpose of the Facilities Study is to facilitate communication between an EGF owner and Hydro-Québec during the design, commissioning and testing phases of an EGF. It achieves this goal by documenting in a single document all the technical information required by Hydro-Québec and the EGF owner regarding the connection.

This study must be completed and signed by an engineer appointed by the EGF owner, at the owner's expense.

In order to guide Facilities Study execution, Hydro-Québec provides a study template and the necessary information to the EGF owner (Appendix F). As the EGF project progresses, the engineer appointed by the EGF owner must provide Hydro-Québec with various technical deliverables compiled within the study.

If the Facilities Study results indicate that modifications to the distribution system are required, the EGF owner may be required to pay a fee in accordance with the *Terms of Service*. These modifications could delay the authorization of commissioning.

The duration of the Facilities Study can vary greatly depending on the complexity of the connection, the studies required and the changes, if any that need to the Hydro-Québec system. In the case of a generating station connection, the Facilities Study must be started at least eighteen (18) months prior to the expected initial power-up date.

The final signed version, including the final settings, must be delivered to Hydro-Québec at least two (2) months prior to the scheduled commissioning. The document must be in PDF format and the signatures must be digital and issued by the Québec Certification Centre.[16] These documents must be submitted electronically.

Final acceptance of the facility cannot be authorized until Hydro-Québec is satisfied with this study and accepts its contents in writing.

[16] For more information on electronic signing of engineering documents, see Notarius at https://www.notarius.com/

The various test reports must be included in the Facilities Study. In order to verify EGF conformity, Hydro-Québec provides a list of minimum tests.

The signed final Facilities Study must be retained by the EGF owner for the life of the facility and made available to Hydro-Québec upon request.

5.10 Typical connection diagrams

Typical examples of single-wire diagrams meeting the requirements of this standard are shown in Appendix B. Table 2 provides the executive summary. Other connection configurations may be acceptable if they meet the requirements of this standard.

Table 2: Summary of connection diagrams in Appendix B

	UL1741-SB certified inverter				**NON**-certified inverter	Generator
	WITH neutral terminal		**WITHOUT** neutral terminal			
	WITHOUT Power transformer	**WITH** Power transformer	**WITHOUT** Power transformer	**with** Power transformer		
WITHOUT Grounding system	LV: Figure 1	LV: Figure 4	LV: Figure 5 and Figure 6	LV: Figure 7	LV: Figure 8	LV: Figure 3
with Grounding system	LV: Figure 9	LV: Figure 2 and Figure 9 MV: Figure 18	LV: Figure 10	LV: Figure 10 MV: Figure 19	LV: Figure 11 and Figure 12 MV: Figure 20	MV: Figure 16 and Figure 17

5.11 Simulation models

The owner of an EGF with a capacity of 250 kW or greater must provide a numerical model of the EGF, suitable for use with the current version of the Siemens PTI PSS/E software. Dynamic models representing the behaviour of generating equipment must be included in the PSS/E library.

The owner of an EGF with a capacity of 250 kW or greater connected to the Hydro-Québec MV system must also provide the information and data necessary to perform electromagnetic transient (EMT) studies by submitting an EMTP model.

Detailed requirements for the simulation models are specified in *Exigences techniques de raccordement de centrales au réseau de transport d'Hydro-Québec* [technical requirements for the interconnection of generating stations to Hydro-Québec's transmission system].

5.12 Construction and connection to the Hydro-Québec system

The EGF owner must obtain written authorization from Hydro-Québec to connect the EGF to the Hydro-Québec system.

Electricity generation equipment must be installed on the EGF side of the main service box and of any disconnecting or metering equipment used by Hydro-Québec, as applicable.

Once construction of the EGF is complete, if the connection authorization has not been issued by Hydro-Québec, an engineer appointed by the EGF owner must lock out the EGF main circuit breaker in the open position (section 5.19). The engineer appointed by the EGF owner must then provide Hydro-Québec with written confirmation of lockout of the EGF main circuit breaker.

Once the connection authorization is received, the EGF owner is authorized to synchronize its generating equipment with the Hydro-Québec system, but solely for the purpose of conducting commissioning testing.

5.13 Changes to a facility

The EGF owner must obtain written authorization from Hydro-Québec before making any modifications to the equipment hardware or software or settings used to protect the Hydro-Québec system or to any other parameters of the IBR inverter or prior to any refurbishment of the EGF.

The EGF owner must submit a written request to Hydro-Québec and attach all relevant documents to the request. Section 5.7 lists the required documents. After reviewing the application, the Hydro-Québec representative will inform the EGF owner if an update to the Facilities Study is required (section 5.9).

Once an EGF has been modified, an inspection and testing by an engineer appointed by the EGF owner may be required (section 5.14)

5.14 Inspection and verification testing

Once the connection is authorized, and before commissioning of generation equipment or after changes to the EGF, testing must be conducted under the supervision of an engineer appointed by the EGF owner. The list of tests is included in the Facilities Study (Appendix F).

If a UTAPP is required by Hydro-Québec (sections 5.2 and 10.5), a Hydro-Québec technician will come to commission the UTAPP and establish communication with the Distribution control centre (DCC). Remote opening and lockout tests will be conducted on the EGF main breaker at this time.

A Hydro-Québec representative will attend the testing if Hydro-Québec deems it necessary. The representative may, among other things:

- Verify the information sent by the EGF owner, including the firmware version of the inverter in the case of an IBR.
- Check that the facilities are compliant with the connection diagram, notably by ensuring that generation equipment is connected on the EGF side of the main service box (section 5.12).
- Check the connection of the neutral to the neutral terminal of the IBR inverter, where applicable.
- Check that safety warnings have been posted where required.
- Check that the manual controls on the EGF main circuit breaker have been properly locked out, where applicable.
- Check that the settings ensuring the protection of the Hydro-Québec system and the behaviour of the EGF in steady state and disturbed state cannot be changed by unauthorized personnel.

Once the tests are complete, a report must be drafted and signed by the engineer appointed by the EGF owner and submitted to Hydro-Québec.

Hydro-Québec will review the test report and, if satisfied, will issue the authorization for continuous production. From that point on, the EGF can generate power on a continuous basis.

5.15 Locking of the EGF's electrical settings

The settings ensuring the protection of the Hydro-Québec system (sections 9.8.3 and 9.8.4), the behaviour of the EGF under steady-state conditions (section 7.1) and the behaviour of the EGF under disturbed conditions (section 7.3) must not be changed without authorization from Hydro-Québec. Locking by means of passwords is acceptable to Hydro-Québec. Access to the settings must be limited to qualified personnel.

5.16 Operations

EGFs of 250 kW or more equipped with a UTAPP must be operated by the EGF owner in accordance with the Hydro-Québec *Work Safety Code* – Distribution chapter.

To this end, an operating agreement must be entered into between Hydro-Québec and the EGF owner. EGF operators must also undergo mandatory training on the application of the Hydro-Québec *Work Safety Code* – Distribution chapter.

5.17 Maintenance

The EGF owner is responsible for the maintenance and periodic inspection of equipment used for the interconnection with the Hydro-Québec system in accordance with Standard E.12-03.

Any system failures related to the protection of the Hydro-Québec system must be reported to Hydro-Québec immediately and corrected as soon as possible.

5.18 Decommissioning

An EGF that is connected to the Hydro-Québec system but has not generated any electricity for over 12 months must be dismantled. Exceptionally, in the event of a force majeure, this grace period may be extended following an agreement to that effect with Hydro-Québec.

When an EGF is dismantled, the EGF owner must:

- Notify Hydro-Québec of its intention to dismantle the generating station if the 12-month period has not elapsed.
- Complete all the work required to remove the facility from the Hydro-Québec system. To do so, the EGF owner must have someone remove the mechanical piece(s) required, such as electrical equipment or conductors, to break the electrical connection between the EGF main power [17] and the Hydro-Québec system.
- Have the EGF inspected by an engineer appointed by the EGF owner in order to obtain a signed written confirmation that the EGF is no longer connected to the Hydro-Québec system. A representative of Hydro-Québec will attend the inspection if deemed necessary by Hydro-Québec.
- Send Hydro-Québec a copy of the confirmation letter from the engineer appointed by the EGF owner who performed the inspection.

Once the confirmation letter is received by Hydro-Québec, the EGF will be removed from the system operation diagram and a Hydro-Québec representative will remove the UTAPP if required.

[17] The main power of an EGF is the electrical path through which energy flows between the generating units and the Hydro-Québec system. In general, auxiliary power is not part of an EGF main power.

5.19 Lockout

Accessories and locks used to lock out EGF equipment must be specifically designed for lockout and with Standard IEEE CSA Z462 section 4.2.3 *Lockout Equipment* and CSA Z460 section 7.3.2 *General Lockout Requirements*.

When a lock is affixed to a device at the request of Hydro-Québec, an information tag must be affixed to the lock. An example of such a tag is provided in Figure 1 of Appendix E.

When a lock is affixed to the push-button switch on the front of the EGF main circuit breaker, an information tag must be affixed to the lock. An example of such a tag is provided in Figure 2 of Appendix E.

5.20 Posting of safety notices

The following safety notices must be posted in any building containing an EGF:

- A notice stating that an EGF is present in the building must be posted either on the meter socket cabinet or the Hydro-Québec metering cabinet. The same notice must also be installed on the distribution panel where the EGF main circuit breaker is installed, where applicable. An example of such a notice is provided in Figure 3 of Appendix E.
- For EGFs of less than 250 kW that do not require a remote control or trip circuit for the main circuit breaker, a notice must be displayed at the disconnect point used to lock out the EGF. This can be a lockable disconnect switch, lockable switch, or lockable circuit breaker. An example of such a notice is provided in Figure 4 of Appendix E.
- For EGFs of 250 kW or more or EGFs that require a remote control or trip circuit for the EGF main circuit breaker, a notice must be displayed on the main circuit breaker. An example of such a notice is provided in Figure 5 of Appendix E.
- For EGFs whose main circuit breaker required the lockout of a push-button switch on the front of the circuit breaker, a notice must be displayed on the main circuit breaker as close as possible to the push-button switch. An example of such a notice is provided in Figure 6 of Appendix E.
- For EGFs equipped with relays designed to protect the Hydro-Québec system, a notice must be posted on the relay cabinet and on the storage battery and static uninterruptible power supply cabinet where applicable. An example of such a notice is provided in Figure 7 of Appendix E.
- For EGFs with a UTAPP, a notice must be posted on the UTAPP cabinet. An example of such a notice is provided in Figure 8 of Appendix E.
- For EGFs with other types of systems required to protect the Hydro-Québec system, such as metering transformers, power systems, interposition relays or telecommunication devices, a notice must be posted on each cabinet in which these systems are present. An example of such a label is provided in Figure 9 of Appendix E.
- For EGFs with a grounding transformer, a notice must be posted on the transformer. An example of such a label is provided in Figure 10 of Appendix E.
- For EGFs equipped with a multimode inverter and a single terminal (section 8.13.6), a noticed must be posted on the inverter. An example of such a label is provided in Figure 11 of Appendix E.

Safety notices must:

- be printed or made with durable material
- be resistant to the environment in which they are located

- remain legible for the planned useful life of the EGF
- be affixed using a permanent adhesive or permanent fasteners

Hydro-Québec recommends the use of engraved lamicoid plates attached to cabinets with screws.

6 Voltage- and frequency-related requirements

6.1 Voltage fluctuations

Operation of an EGF must not cause voltage at the Point of Connection or at any other point on the Hydro-Québec distribution system to exceed the normal operating limits described in section 4.1.

Flicker level at the Point of Connection caused by the EGF must be within the limits specified in Standard C.22-03, *Exigences techniques relatives au raccordement des charges fluctuantes au réseau de distribution d'Hydro-Québec* [technical requirements for the interconnection of fluctuating loads to the Hydro-Québec distribution system]. Voltage fluctuations to be considered when calculating flicker exclude transient events lasting less than t 60-Hz periods. Such fluctuations may, for instance, be caused by capacitor bank switching, and by starting up or shutting down motors or generators.

The maximum allowable voltage flicker is specified as a function of the frequency of the fluctuations.

In the event that the EGF has more than one piece of equipment that can cause voltage fluctuations, for example in ancillary services equipment, their cumulative effects must be evaluated in accordance with Standard C.22-03 *Exigences techniques relatives au raccordement des charges fluctuantes au réseau de distribution d'Hydro-Québec* [technical requirements for the interconnection of fluctuating loads to the Hydro-Québec distribution system].

The EGF owner's engineer must calculate voltage fluctuations using data from the Hydro-Québec system at the Point of Connection if the facility contains equipment likely to cause voltage fluctuations. To this end, Hydro-Québec will provide the minimum short-circuit level and the location of the Point of Connection to be used for the calculations.

6.2 Harmonic distortion

The EGF owner's engineer must calculate harmonic disturbances using data from the Hydro-Québec system at the Point of Connection if the facility contains equipment likely to produce harmonics. Specific instructions on the calculation method to be used can be found in Standard C.25-01, *Exigences techniques relatives à l'émission d'harmoniques par les installations de clients raccordées au réseau de distribution d'Hydro-Québec* [technical requirements for harmonic emissions by customer facilities connected to the Hydro-Québec distribution system]

When any of the harmonic disturbance limits are exceeded, the EGF must be modified or equipped with filters to limit the emission of harmonic currents into the Hydro-Québec system. When such filters are required, the EGF owner's engineer must reevaluate the previous indicators to demonstrate that the EGF has complied with the prescribed limits by adding filters. Hydro-Québec may require system that other measures be implemented on the system to ensure that the EGF complies with the prescribed limits.

6.3 Injection of direct current

No EGF should, under any circumstances, generate direct current with an amplitude exceeding 0.5% of its nominal current. Although this requirement is a general one, it applies more specifically IBRs.

6.4 Immunity to voltage variations

The EGF must be designed with the ability to generate its full operating power when voltage at the Point of Connection is maintained within +10%/-12% of the nominal voltage of the LV distribution system and within +10%/-10% of the nominal voltage of the MV distribution system.

6.4.1 Undervoltage and overvoltage ride-through

Table 3 and Table 4 show the requirements for undervoltage and overvoltage ride-through.[18]

Appendix G: presents overlay graphs showing the undervoltage and overvoltage ride-through requirements and protection thresholds

Table 3: Minimum ride-through duration for undervoltage and overvoltage at an EGF

Voltage (% of nominal voltage)[1]	Ride-through duration[2]	Operating mode[3]
137% < V	0.033 seconds	Must remain in operation
125% < V 137%	0.1 seconds	Must remain in operation
120% < V 125%	2 seconds	Must remain in operation
110% < V 120%	12 seconds	Must remain in operation
88% ≤ V ≤ 110%	Tripping prohibited	Continuous operation
70% ≤ V < 88%	20 seconds	Must remain in operation
50% ≤ V < 70%	10 seconds	Must remain in operation
V < 50%	1 second	Must remain in operation

1. RMS voltage at fundamental frequency for a single-phase EGF. Phase-to-neutral and phase-to-phase RMS voltage for each of the phases of a three-phase EGF. If one of the phases reaches the trip threshold, the EGF must trip on all three phases.
2. Minimum durations for which EGF must remain in service without tripping (tripping prohibited) following a disturbance.
3. Expected EGF behaviour during disturbance ride-through

[18] These requirements are based on the values in Tables 8 and 9 of section 12.2 *Exigences techniques de raccordement de centrales au réseau de transport d'Hydro-Québec* [technical requirements for the interconnection of generating stations to the Hydro-Québec transmission system] as well as on section 6.4 of Standard IEEE 1547-2018.

Table 4: Minimum duration of undervoltage and overvoltage ride-through for EGFs with a capacity of less than 250 kW using IBRs and UL1741-SB certified inverters

Voltage (% of nominal voltage) [1]	Ride-through duration[2]	Operating mode[3]
137% < V	Instantaneous[4]	Can block or trip
125% < V 137%	Instantaneous[4]	Can block or trip
120% < V 125%	Instantaneous[4]	Can block or trip
110% < V 120%	12 seconds	Must block
88% ≤ V ≤ 110%	Tripping prohibited	Continuous operation
70% ≤ V < 88%	20 seconds	Must remain in operation
50% ≤ V < 70%	10 seconds	Must remain in operation
V < 50%	1 second	Must block

1. RMS voltage at fundamental frequency for a single-phase EGF. Phase-to-neutral and phase-to-phase RMS voltage for each of the phases of a three-phase EGF. If one of the phases reaches the trip threshold, the EGF must trip on all three phases.
2. Minimum durations for which EGF must remain in service without tripping (tripping prohibited) following a disturbance.
3. Expected behaviour of EGF during disturbance ride-through.
4. The term “Instantaneous” refers to permission to issue a trip order without intentional delay.
5. A UL1741-SB certified inverter is considered compliant.

6.5 Negative-sequence voltage immunity

The EGF must be designed to generate full power and operate continuously in the presence of negative-sequence voltage at the customary Point of Connection to the Hydro-Québec system, in addition to continuing to operate during exceptional events.

Hydro-Québec aims to deliver a voltage on its system that includes:[19]

- a negative-sequence voltage (V_2/V_1) of less than 2% under normal operating conditions
- a negative-sequence voltage (V_2/V_1) of less than 3% for a system with long two-phase or single-phase connectors

and this, 95% of the time over a one-week period.

For extreme events, the EGF must continue to operate uninterrupted under the following conditions:[20]

- negative-sequence voltage of 6% for 30 seconds
- negative-sequence voltage of 13% for 15 seconds
- negative-sequence voltage of 25% for 0.1 second

[19] Extract from *Caractéristiques de la tension fournie par les réseaux moyenne et basse tension d’Hydro-Québec* [characteristics of the voltage supplied by the Hydro-Québec medium- and low-voltage systems].
[20] Excerpt from Table 1 of Standard CSA IEC 61000-4-27:01 (renewed in 2024).

6.6 Zero-sequence voltage immunity

Taking into account its contribution to the zero-sequence current related to the characteristics of the Hydro-Québec system, the EGF must be designed to generate full power and operate continuously in the presence of the zero-sequence voltage typically found on the Hydro-Québec distribution system, in addition to continuing to operate during exceptional events.

Under normal operating conditions, the EGF must be immune to zero-sequence voltage imbalances (V_0/V_1) of up to 4%.

In the case of exceptional events, the EGF must continue to operate uninterrupted in the event of a phase-to-ground fault on an adjacent line.[21] To this end, the protection coordination section of the Facilities Study (section 5.9) must take into account the EGF's contribution to the zero-sequence current in a solid phase-to-ground fault on an adjacent line. Should the event last more than 1 second, which corresponds to the ride-through time for an undervoltage of less than 50% of the nominal voltage, as defined in Table 3 andTable 4, then it would be acceptable for the EGF to cease operation due to tripping of its backup protection (section 9.1.2).

6.7 Frequency variation immunity

The EGF must be designed to generate full operating power when the frequency at the Point of Connection is maintained within the 59.4 to 60.6 Hz range.

6.7.1 Frequency variation speed

The EGF must be designed to remain in service during frequency variations of -4 Hz/second to +4 Hz/second.

6.7.2 Frequency variation ride-through

Table 5 and Table 6 show the requirements for frequency variation ride-through.[22]

Appendix G: presents overlay graphs showing ride-through requirements and protection thresholds.

[21] The short-circuit studied must be located directly downstream of the circuit breaker that has the slowest setting and is powered by the same interconnection substation busbar as the EGF line. The duration of the short circuit must match the opening time of the circuit breaker at its slowest setting. A typical value of 150 ms can be used in the absence of accurate data.

[22] These requirements are based on the values in Table 4 of section 6.6.3 and Table 10 of section 12.2.3 *Exigences techniques de raccordement des centrales au réseau de transport d'Hydro-Québec*. [technical requirements for the interconnection of generating stations to the Hydro-Québec transmission system].

Table 5: Minimum duration of frequency variation ride-through by an EGF

Frequency (Hz)	Ride-through duration[2]	Operating mode[4]
63.5 < f	Instantaneous	May remain in operation or trip
63 < f ≤ 63.5	5 seconds	Must remain in operation
61.5 < f ≤ 63 [1]	90 seconds	Must remain in operation
60.6 < f ≤ 61.5	660 seconds	Must remain in operation
59.4 ≤ f ≤ 60.6	Tripping prohibited	Continuous operation
58.5 ≤ f < 59.4	660 seconds	Must remain in operation
57.5 ≤ f < 58.5	90 seconds	Must remain in operation
57.0 ≤ f < 57.5	10 seconds	Must remain in operation
56.5 f < 57.0	2 seconds	Must remain in operation
55.5 ≤ f < 56.5	0.35 second	Must remain in operation
f < 55.5	Instantaneous[3]	May remain in operation or trip

1. Instantaneous tripping is allowed starting at 61.7 Hz for the following EGFs:
   a) EGFs equipped with synchronous generators having a total capacity less than or equal to 250 kW
   b) Thermal and gas turbine EGFs
   c) EGFs equipped with asynchronous generators
   d) EGFs with IBR
2. Minimum durations for which EGFs must remain in service without tripping (tripping prohibited) following a disturbance.
3. The term “instantaneous” refers to permission to trip without intentional delay
4. Expected behaviour of EGF for the duration of disturbance ride-through

Table 6: Minimum ride-through duration for frequency variations in EGFs of less than 250 kW using IBRs and a UL1741-SB certified inverter

Frequency (Hz)	Ride-through duration[1]	Operating mode[3]
61.7 ≤ f	Instantaneous[2]	Can remain in operation or trip
61.5 < f < 61.7	90 seconds	Must remain in operation
60.6 < f ≤ 61.5	660 seconds	Must remain in operation
59.4 ≤ f ≤ 60.6	Tripping prohibited	Continuous operation
58.5 f < 59.4	660 seconds	Must remain in operation
57.5 ≤ f < 58.5	90 seconds	Must remain in operation
57.0 ≤ f < 57.5	10 seconds	Must remain in operation
56.5 ≤ f < 57.0	2 seconds	Must remain in operation
55.5 ≤ f < 56.5	0.35 second	Must remain in operation
f < 55.5	Instantaneous[2]	Can remain in operation or trip

1. Minimum durations for which EGF must remain in service without tripping (prohibited tripping) following a disruption.
2. The term “instantaneous” refers to permission to trip without intentional delay
3. Expected behaviour of EGF for the duration of disturbance ride-through
4. A UL1741-SB certified inverter is considered compliant.

6.8 Immunity to phase angle changes

The EGF must be designed to remain connected when the voltage phase angle changes instantly by up to 60° for a single-phase event and 20° for a three-phase event. This can occur during undervoltage and overvoltage ride-through events.

7 EGF behaviour-related requirements

7.1 EGF startup

7.1.1 Startup conditions

In order for an EGF to initiate its startup sequence and begin producing power, the following criteria must be met:

- The voltage at the Point of Connection must be stabilized within the range of marginal operating conditions presented in Table 1.
- The frequency must be stabilized within the range of normal operating conditions defined in section 4.1.
- In the case of an EGF connected at a customer facility and operated with minimum load protection (section 9.1.3) or protection to limit injection of power (section 9.1.4), it is recommended that a protection system (section 9.1.6) ensures that the electrical load conditions of the facility are sufficient to allow the resumption of production without tripping the primary protection.

Once the above conditions have been met, an initial startup delay of at least five (5) minutes must be observed, during which the above startup criteria must be maintained. This delay must be applied when an EGF is restarted after tripping or after an outage on the Hydro-Québec distribution system.[23]

When starting up an EGF with a capacity of less than 500 kW, a random delay following a uniform distribution between zero (0) and three hundred (300) seconds must be added to the initial startup time of five (5) minutes, once the prerequisite conditions have been met.

In the case of an EGF with a capacity of 500 kW or more, after the initial five (5) minutes of startup time has elapsed, the EGF must increase its output linearly at an average ramp rate not exceeding the EGF's nominal active power divided by six hundred (600) seconds.

7.1.2 Synchronization tolerances

An EGF that produces voltage at the fundamental frequency of the Hydro-Québec system before being electrically connected to it must meet the synchronization tolerances specified in Table 7 before the EGF main circuit breaker is closed to perform phase synchronization.

Table 7: Maximum synchronization tolerances during phasing of an EGF with the Hydro-Québec system[24]

EGF total power (kVA)	Frequency matching (Δf, Hz)	Voltage matching (ΔV, %)	Phase angle matching ($\Delta\Phi$, degree)
0–500	0.3	10	20
>500–1500	0.2	5	15
>1500	0.1	3	10

During the synchronization operation, the voltage disturbance level at the point of connection must meet the requirements of Standard C.22-03 (section 7.1). If necessary, tighter synchronization tolerances will be required.

7.1.3 Synchronization voltage

The voltage level at which the synchronization operation can be executed depends on the capacity of the power producer facilities and the characteristics of the Hydro-Québec system. To prevent tripping of the rapid phase protection system on the Hydro-Québec circuit breaker involved when power producer transformers are energized, the power producer may need to energize its transformers before synchronizing with the Hydro-Québec system. Refer to section 8.12.3 for details on power transformer inrush current.

Hydro-Québec will inform the power producer of the voltage level at which the synchronization operation is to be performed.

[23] In accordance with the undervoltage ride-through requirement (section 6.4.1) and the voltage protection requirement (section 9.8.3), an outage is characterized by a voltage of less than 50% of the nominal phase-to-neutral and phase-to-phase voltage for each of the phases, and lasting 2 seconds or more.
[24] Excerpt from Table 5 of Standard IEEE 1547-2018.

7.1.4 Synchronization of synchronous generators

Synchronization of synchronous generators to the distribution system must be done using a generator synchronism check system (function 25) while meeting voltage fluctuation requirements (section 6.1).

7.1.5 Synchronization of asynchronous generators

Synchronization of asynchronous generators with the Hydro-Québec system must be done when the generators are close their rated speed in order to meet the voltage fluctuation requirements (section 6.1).

7.2 Steady state

Steady-state voltage is defined as the voltage range between 88% and 110% of the nominal voltage for an LV connection and the voltage range between 94% and 106% of the nominal voltage for an MV connection.

Steady-state frequency is defined as the frequency range between 59.4 and 60.6 Hz.

7.2.1 Design power factor

EGFs with a capacity of 5 MW or less must be capable of supplying and absorbing the amount of reactive power corresponding to a leading or lagging power factor of 0.95 or greater at the Point of Connection, while EGFs with a capacity greater than 5 MW must be capable of supplying and absorbing the amount of reactive power corresponding to a leading and lagging power factor of 0.9 or greater at the Point of Connection. This requirement applies in steady state when the EGF is operating at its rated capacity, both when the EGF injects active power at the Point of Connection and when it absorbs power (hybrid EGF or energy storage system), and this across its entire intended operating temperature range.

However, as shown in Figure 1, an EGF connected to LV at a voltage less than 92% of the nominal phase-to-neutral voltage is not required to absorb reactive power corresponding to a lagging power factor of 0.95, But it still must be able to supply reactive power corresponding to a leading power factor of 0.95. Similarly, at voltages greater than 104% of the nominal phase-to-neutral voltage, the EGF is not required to supply reactive power corresponding to a leading power factor of 0.95, but it still must be able to absorb reactive power corresponding to a lagging power factor of 0.95.

In addition, as shown in Figure 2, an EGF connected to MV at a voltage less than 95.8% of the nominal phase-to-neutral voltage is not required to absorb reactive power corresponding to a lagging power factor of 0.95 for EGFs with a capacity of 5 MW or less, or of 0.9 for EGFs with a capacity greater than 5 MW. However, it still must be able to supply reactive power corresponding to a leading power factor of 0.95 for EGFs with a capacity of 5 MW or less or 0.9 for EGFs with a capacity greater than 5 MW. Similarly, at voltages greater than 104.2% of the nominal phase-to-neutral voltage, the EGF is not required to supply reactive power corresponding to a leading power factor of 0.95, for EGFs with a capacity of 5 MW or less, or 0.9 for EGFs with a capacity greater than 5 MW, but must nevertheless be able to absorb reactive power corresponding to a lagging power factor of 0.95 for EGFs with a capacity of 5 MW or less, or 0.9 for EGFs with a capacity greater than 5 MW.

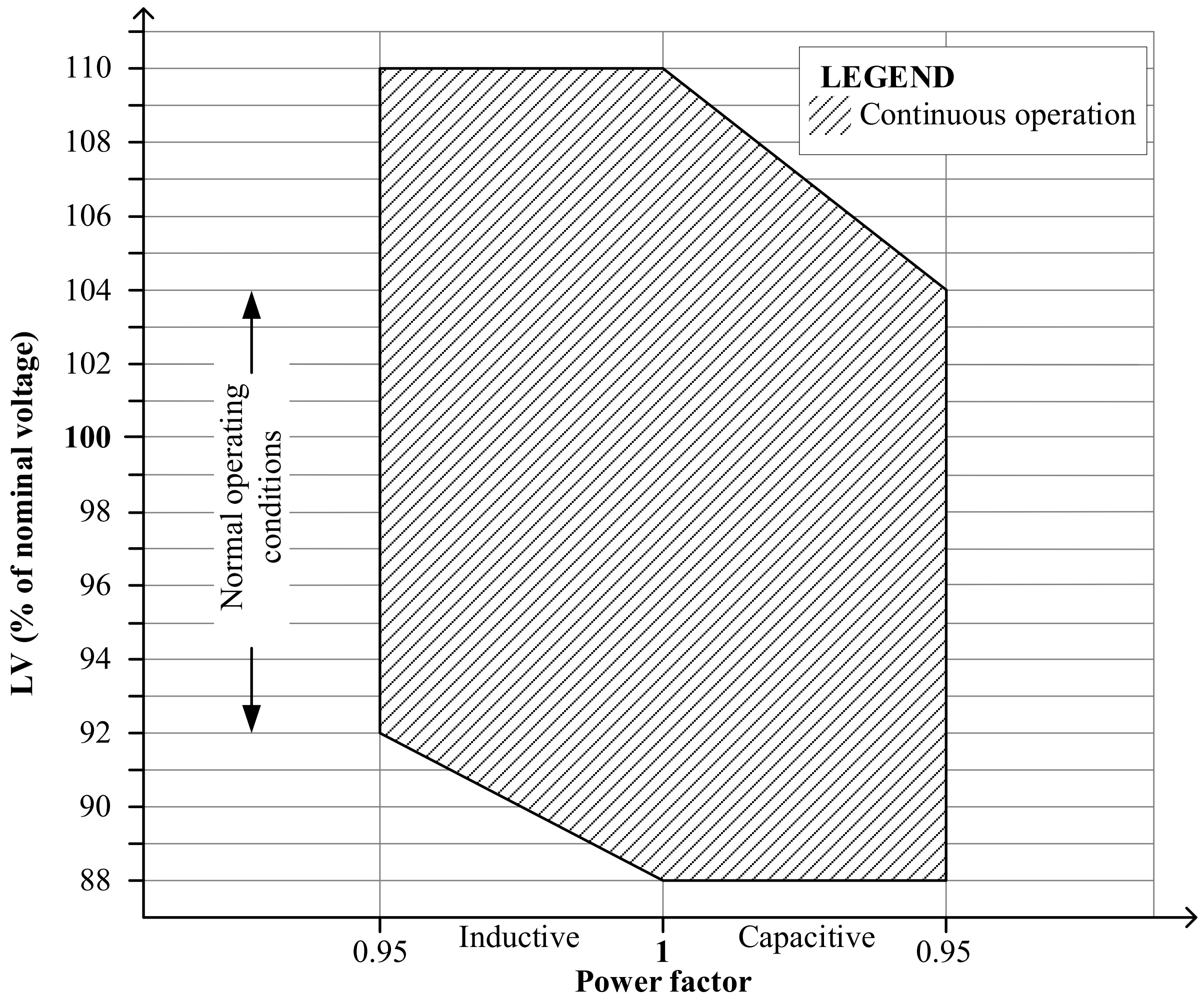


Figure 1: Reactive power available at the Point of Connection of an EGF connected to LV based on the phase-to-neutral voltage

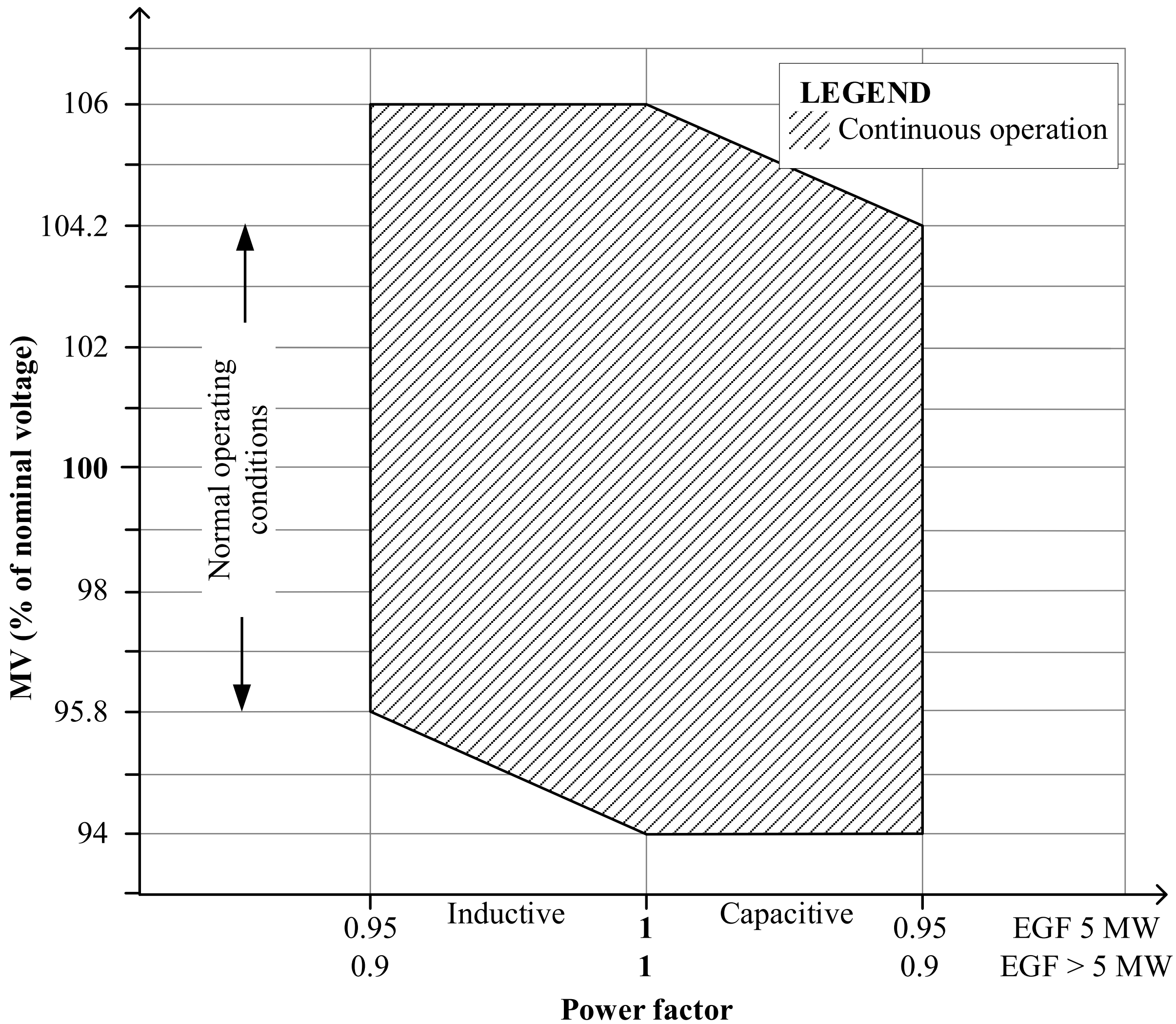


Figure 2: Reactive power available at the Point of Connection of an EGF connected to MV based on phase-to-neutral voltage

7.2.2 Maximum ramp rates for active power ramp-ups and ramp-downs

EGFs with a capacity of 250 kW or greater must be designed to comply with the following maximum ramp rates when ramping up or ramping down its active power output:

- Ramp up in an adjustable 2- to 60-minute minimum from 0 MW (stopped) to Pmax (maximum power plant output)
- Ramp down in an adjustable 2- to 60-minute minimum from Pmax (maximum power plant output) to 0 MW (stopped)

During power fluctuations in the course of normal operation, the EGF must meet the voltage fluctuation requirements described in section 6.1.

Unless explicitly directed by Hydro-Québec, minimum ramp-up and ramp-down time is 10 minutes.

7.2.3 Energy storage system charging power limit under Cold Load Pickup (CLPU) conditions

An EGF that includes an energy storage system must be designed in such a way that it can limit storage system charging power during the recovery period following an interruption in the power supply to the Hydro-Québec system. The following parameters, presented in Figure 3, must be configurable:

- An adjustable delay of 0 to 240 minutes from the end of the power interruption before charging resumes ($T_{DelayCLP\_RechargeESS}$). The default value is 60 minutes.
- An adjustable delay of 0 to 720 minutes following the resumption of charging, during which the charging power will be limited ($T_{LimitCLP\_RechargeESS}$). The default value is 240 minutes.
- A charging power limit ($P_{LimitCLP\_RechargeESS}$) in the range between 0 MW and the maximum charging power of the energy storage system ($P_{\max\_RechargeESS}$) during the period $T_{LimitCLP\_RechargeESS}$. The default value is 25 percent of $P_{\max\_RechargeESS}$.

Variables $T_{DelayCLP\_RechargeESS}$, $T_{LimitCLP\_RechargeESS}$ and $P_{LimitCLP\_RechargeESS}$ must be remotely configurable (section 10.19.8.5).

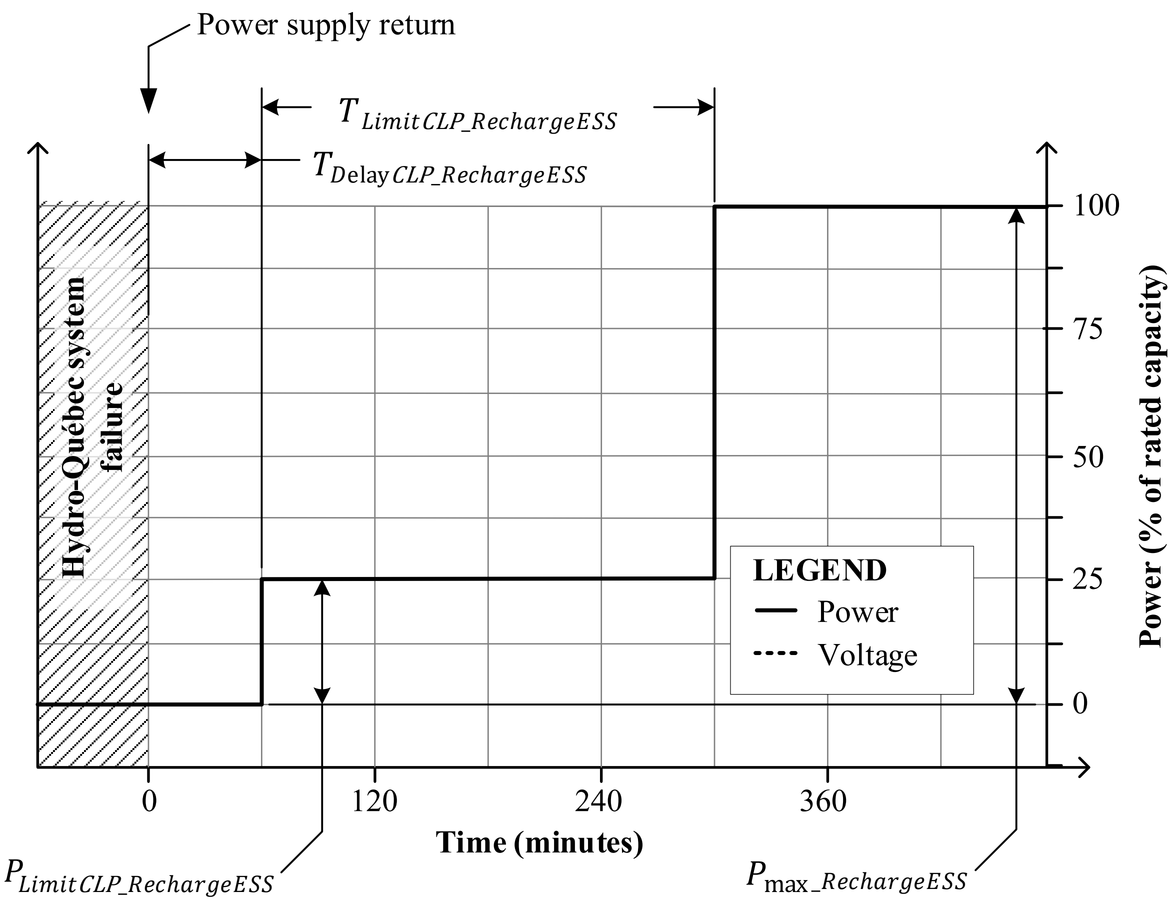


Figure 3: Energy storage system failure recovery

7.2.4 EGF shutdown in anticipation of severe weather conditions

EGFs must be designed and built to allow for gradual shutdown over a period of 1 to 4 hours when forecasted cold temperatures, high winds, freezing rain, rapid clouding-over, heavy snowfall, solar eclipse or any other natural phenomenon or any severe weather conditions require their gradual shutdown.

7.2.5 Active power control (Watts)

An EGF must make available each of the following active power control modes:

- Volt-watt control[25]
- Hertz-watt control[25]

Hydro-Québec will inform the EGF owner of the operating mode and settings of the active power control to be implemented at the EGF. However, each of the specified operating modes must remain available.

[25] See the *IEEE Std 1547 Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces* for details on regulator operation.

In the case of an EGF connected at a customer facility and operated with a protection system to ensure minimum load (section 9.1.3) or limit injection of power (section 9.1.4), it is recommended that the EGF be equipped with an active power control to ensure that the directional protection relay trip threshold is not reached. A peak-shaving or load-following operation with minimum consumption monitoring is recommended.

EGFs with a capacity greater than 10 MW must also comply with the frequency control requirements in sections 6.4.3 or 12.4 of *Exigences techniques de raccordement de centrales au réseau de transport d'Hydro-Québec* [technical requirements for the interconnection of generating stations to the Hydro-Québec transmission system].

In the case of an EGF with a capacity of 10 MW or less equipped with synchronous generators, Hydro-Québec does not require EGF generating units to be equipped with speed governors unless it specifies otherwise. If a speed governor not required by Hydro-Québec is installed, it must be disabled (frequency-controlled speed regulation must be switched off) when the generating unit is synchronized with the distribution system to reduce the risk of extended islanding. Use of the speed governor during generation that is synchronized with the distribution system may require the use of a remote tripping function to ensure separation of the generating station from the system.

7.2.6 Reactive power control (Vars)

An EGF must make available each of the following modes of reactive power control:

- Constant power factor mode
- Voltage-reactive power mode [25]
- Active power-reactive power mode[25]
- Constant reactive power mode

Hydro-Québec will inform the EGF owner of the operating mode and settings of the reactive power control to be implemented at the EGF. However, each of the planned operating modes must remain available.

Unless otherwise specified by Hydro-Québec, an EGF must maintain a unit power factor (PF) at the Point of Connection. However, Hydro-Québec may require a different PF within the reactive power range that the EGF must make available to the grid in steady state (section 7.2.1).

The PF instruction assigned based on time (such as time of year)by Hydro-Québec may take the form of a constant value, a value assigned based on time (such as time of year) or other conditions determined by Hydro-Québec.

The operation of the reactive power control must not interfere with the proper operation of the backup protection or anti-islanding protection required in section 9.1.2.

Some restrictions apply when capacitors are installed at the EGF to compensate, for example, the PF at the Point of Connection. Section 8.8 outlines these restrictions.

Hydro-Québec may accept that an EGF using asynchronous generators not be equipped with an automatic reactive power control system, particularly if the short-circuit level at the Point of Connection is significantly higher than the installed capacity of the EGF.

Reactive power control can be provided by the generating units at the EGF or by additional compensatory equipment that is part of the EGF.

7.3 Under disturbance conditions

The EGF and all of its equipment must remain in service, without any generating units being directly or indirectly tripped, during and after voltage and frequency variations that fall within the no-trip zones for voltage variations (section 6.4), negative-sequence voltage (section 6.5), zero-sequence voltage (section 6.6), frequency variations (section 6.7) and phase angle changes (section 6.8). EGF equipment includes generators, the various auxiliary systems, control systems and compensation equipment.

To this end, the following requirements must be met:

1. The reference point for no-trip requirements is the Point of Connection.
2. During a system event, EGFs with a capacity of 250 kW or greater must be able to support the system during voltage drops by providing additional reactive current. In the case of an asymmetric event, the EGF must provide not only positive sequence reactive current, but also negative-sequence reactive current. For this purpose, it is subject to the requirements of Standard IEC 62786-1.
3. EGFs with a capacity of 250 kW or greater must be designed and built to ride through multiple consecutive system events:
    - An EGF using synchronous generating units is allowed to disconnect from the system when the thermal limits of one or more generating units are exceeded as a result of a system event sequence.
    - An EGF using IBRs must be able to ride through any sequence of system events until the total accumulated energy that could not be sent to the system due to system events during the preceding 30 minutes exceeds the equivalent energy generated by the EGF when operating at full power for 2 seconds. Load banks may be used for this purpose when required.
    - If axle oscillations or similar mechanical oscillations occur as a result of a sequence of system events, the affected generating units or the EGF, as the case may be, are allowed to disconnect for protection.

7.3.1 Short-circuit current contribution

The contribution of an EGF to the interrupted short-circuit current[26] must not exceed the capacity of EGF and Hydro-Québec equipment nor generate total short-circuit currents on the Hydro-Québec distribution system exceeding 87.5% of the interrupting capability of the system and interconnection substation protection devices.[27]

The maximum short-circuit current value for which Hydro-Québec 25 kV mean voltage array equipment is designed is 12 kA RMS symmetrical for a three-phase fault and 8 kA RMS symmetrical for a phase-to-ground fault.

[26] The interrupted short-circuit current is defined as the short-circuit current at the time the first contact of the protection device intended to interrupt the short circuit opens. Thus, the contribution of an EGF to the interrupted short-circuit current is the maximum contribution of the EGF to the short-circuit currents within a time window starting at 1.5 cycles after the start of the short-circuit and ending at 10 cycles after the start of the short circuit.
[27] For Hydro-Québec employees, Standard E.12-02 *Planification du réseau de distribution d'Hydro-Québec pour l'intégration de la production décentralisée* [Hydro-Québec distribution system planning for the interconnection of distributed generation] provides more details on this point.

If the short-circuit current on the medium-voltage system is increased by the EGF and exceeds the allowable limit, Hydro-Québec will require that mitigation measures be put in place by the EGF owner.

7.3.2 Contribution to temporary overvoltages

When an EGF is connected to the Hydro-Québec system or following the creation of an involuntary island, the EGF must not contribute to a temporary overvoltage level[28] exceeding 138% of the nominal phase-to-phase and phase-to-neutral voltage for a duration of more than 17 ms in the event of a phase-to-ground short-circuit or a load rejection on the system to which the EGF is connected.

This requirement is met when:

- the neutral system at the EGF Point of Connection and across the medium-voltage interconnection line is effectively grounded (section 5.3) or
- the grounding coefficient at the Point of Connection of an EGF using IBRs and over the entire medium-voltage interconnection line is less than 0.8 (section 5.3.1) or
- EGFs with a capacity of less than 250 kW using IBRs:
  - include an inverter with a phase-to-neutral and phase-to-phase surge detection circuit compliant with section 7.4 of Standard IEEE 1547-2018 *Limitation of overvoltage contribution* and
  - the inverters have been validated according to section SB4.3.5.17 of Standard UL1741-SB *Limitation of overvoltage contribution* and
  - The EGF power wiring provides zero-sequence continuity from the EGF Point of Connection with the Hydro-Québec system to the inverters (section 8.5) and
  - The EGF power transformers (section 8.12), where applicable, provide zero-sequence continuity from the EGF Point of Connection with the Hydro-Québec system to the inverters.

  or
- the risk assessment for temporary overvoltage associated with connecting an EGF using IBRs and installed at a Self-generation customer's premises (section 5.3.2), as described in the flowchart in Appendix D, concludes that there is no risk of temporary overvoltage in case of a phase-to-ground fault or a load rejection.

7.3.3 Contribution to transient overvoltages

An EGF must not contribute to transient overvoltages[29] that would cause the maximum operating voltage of Hydro-Québec equipment to be exceeded (section 8.2).

[28] IEC defines a temporary overvoltage as having a duration of more than 8.33 milliseconds, but equal to or less than one minute.
[29] IEC defines a transient overvoltage as having a duration of a few milliseconds or less.

8 Requirements regarding EGF equipment

8.1 Choice of generation equipment

The choice of generation equipment is at the discretion of the EGF owner, except in cases where the EGF could compromise voltage regulation or the stability of the Hydro-Québec system. In these cases, Hydro-Québec may require that the EGF be equipped with synchronous generators or IBRs capable of producing or absorbing sufficient reactive power to ensure proper operation of the Hydro-Québec system (section 7.2).

8.2 Electrical characteristics of EGF equipment

The electrical characteristics of equipment making up EGFs must be compatible with those of the distribution system to which these facilities are connected, especially with regards to insulation coordination. Table 8 gives current standard values for insulation and short-circuit levels on the LV distribution system. Table 9 gives the characteristics for 25 kV equipment taken from Standard E.21-12. When an EGF is connected to MV at a voltage other than 25 kV, Hydro-Québec will inform the EGF owner of the requirements specific to the line in question.

In designing its facilities, the EGF owner must check with Hydro-Québec to confirm the electrical characteristics that apply to the portion of the distribution system to which its facilities are to be connected.

Table 8: Standard insulation and short-circuit levels for Hydro-Québec LV distribution system equipment

Nominal system voltage (RMS volts)	Rated voltage[1] (RMS volts)	Basic impulse insulation level (BIL) (kV rms)	Standard short-circuit level (kA sym. rms)
120/240	127/254	10	22 [2] 45 [3]
347/600	367/635	10	22 [2] 11.7 – 96.1[3]

1. Rated voltage is the highest level of phase-to-phase voltage for which the equipment is intended to operate in continuous service A higher operating voltage may be present in the system, as indicated in *Caractéristiques de la tension fournie par le réseau de transport d'Hydro-Québec*.
2. Connection as per Standard E.21-10.
3. Connection as per Standard E.21-11.

Table 9: Characteristics of equipment powered at 25 kV

Characteristics	Value	Applicable standard
Maximum RMS operating voltage for a nominal system voltage of 24.9 kV	26.4 kV	CAN-3C235F83F83 (R2015)
Minimum power-frequency withstand voltage for 1 minute	60 kV (RMS)	IEC 62271-100
RMS withstand test voltage of the assembly at power frequency for 1 minute (phase-to-ground)	50 kV (RMS)	CSA C22.2 No. 31-18:

Minimum power-frequency withstand voltage For 1 minute across the Isolating distance (between open contacts)	66 kV (RMS)	IEC 62271-100
Minimum lightning impulse withstand voltage to earth	125 kV (peak)	–
Minimum lightning impulse withstand voltage between the open contacts of a switching device (i.e., 125 kV + 10%)	137.5 kV	–
Minimum symmetrical breaking capacity on a three-phase fault (for circuit breakers) with an aperiodic component	12.5 kA	IEC 62271-100
Minimum single-phase breaking capacity	8.1 kA	IEEE Std C37.48
Minimum asymmetrical making current on a three-phase transient fault with a 2.6 crest factor	32.5 kA (peak)	IEC 62271-100
20-cycle short duration RMS test current	12.5 kA	IEC 62271-100
Rated voltage for surge arresters (phase-to-ground) Service cycle voltage (duty-cycle voltage) *18 kV voltage class: maximum voltage in continuous operation (MCOV) = 15.3 kV 21 kV duty-cycle voltage: maximum continuous operation voltage (MCOV) = 17 kV	18 kV or 21 kV*	IEEE C62.11-2020

8.3 Zero-sequence current source

Given that the presence of a zero-sequence current source complicates the operation of the distribution system, Hydro-Québec wishes to limit the number and contribution of these current sources. Installation of a zero-sequence current source must therefore be authorized by Hydro-Québec, and its characteristics must be submitted for approval.

When a zero-sequence current source is required to maintain an effectively grounded neutral system (in the case of generators) or a grounding coefficient (in the case of IBRs) (section 5.3), three options are available to EGF owners. The criteria in Table 10 are designed to guide the choice of the method used.

For the IBR connection, Hydro-Québec recommends using a Y(neutral)-Y(Grounded) power transformer combined with a grounding transformer independent of the power transformer. For multiple generator connections, Hydro-Québec recommends the use of Y-ALL or Delta-ALL power transformers, combined with a grounding transformer independent of the generator power transformers.

The zero-sequence current source connection type and impedance value must be the subject of an engineering study recorded in the Facilities Study (section 5.9) and must be approved by Hydro-Québec.

Table 10: Zero-sequence current source connection types

Connection type (System side - EGF side)	Figures Appendix B	Special conditions	Advantages
Y(Neutral)-Y(ground) Grounding transformer[1]	LV: Figure 2 and Figure 9 MV: Figure 18		Ensures zero-sequence continuity to the generating units. Provides predictable zero-sequence current in the protection relays, regardless of the number of generating units in operation.
Y-ALL or Delta-ALL + UPSTREAM grounding transformer [1]	LV: Figure 10 MV: Figure 19 and Figure 20	Voltage and frequency protection must be installed upstream of the power transformer (section 9.8). Required when multiple power transformers are needed.	Allows for galvanic isolation between the system and the generating units. Provides a predictable zero-sequence current in the protection relays, regardless of the number of generating units in operation.
Y(neutral)-Delta[1]	LV: Figure 11 MV: Figure 16 and Figure 17	Only one power transformer is allowed. Voltage and frequency protection must be installed upstream of the power transformer (section 9.8) Ground impedance may be required (section 8.4).	Allows for galvanic isolation between the system and the generating units.

1. Ground resistance or impedance may be required between the transformer H0 terminal and the neutral. See section 8.4 for more details.

Figure 4, Figure 5 and Figure 6 below show the connection of a zigzag grounding transformer, a Y(neutral)-delta grounding transformer and a Delta(neutral)-Y(neutral) power transformer.

When a grounding transformer is required:

- Hydro-Québec requires that the transformer be equipped with a connection point to the transformer's neutral terminal so that the neutral-to-ground connection can be made at the time of installation rather than at the factory, or that a neutral resistance or inductance can be installed as required.
- The level of insulation and lightning impulse withstand for the neutral terminal must be the same as for the phase terminals.

The design of the zero-sequence current source must take into account the maximum negative-sequence voltage imbalance (section 6.5) and the maximum zero-sequence voltage imbalance (section 6.6) that may occur at the connection point. Thus, the power of the grounding transformer and the neutral inductance or resistance (section 8.4) must be calculated in order to operate continuously with a negative-sequence voltage imbalance on this scale. Method A.5-09 *Application d'un transformateur de mise à la terre dans une IPE équipée de SERMO et raccordée au réseau de distribution d'Hydro-Québec* [application of a grounding transformer in an EGF using IBRs connected to Hydro-Québec's distribution system] provides more details on how to design the zero-sequence current source for a facility using IBR.

The presence of a zero-sequence current source may also require the addition of additional accessories such as a circuit breaker for grounding transformer protection, an electronic trip unit, current transformers, a neutral resistor or impedance (section 8.4), protection relays, trip coils, etc.

It is prohibited to power loads from a grounding transformer used as a zero-sequence power source for the Hydro-Québec system. A warning to this effect must be affixed to the grounding transformer (section 5.20).

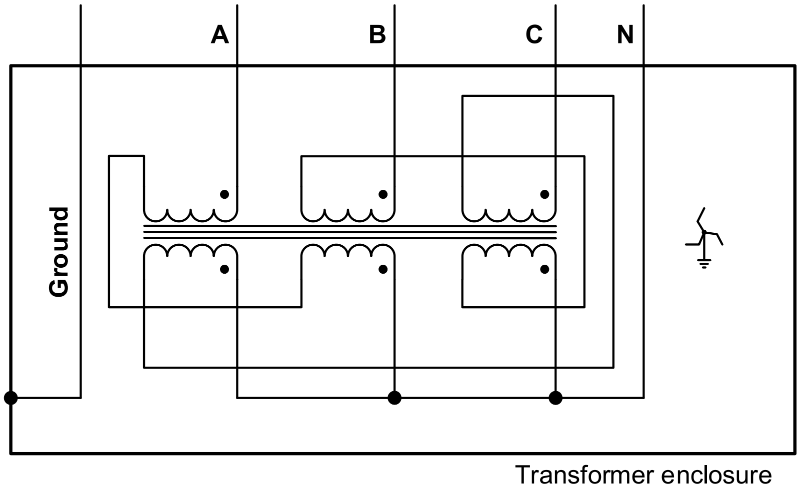


Figure 4: Zigzag grounding transformer connection

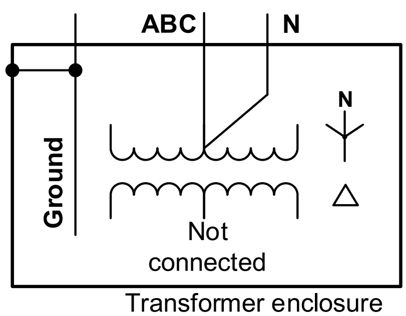
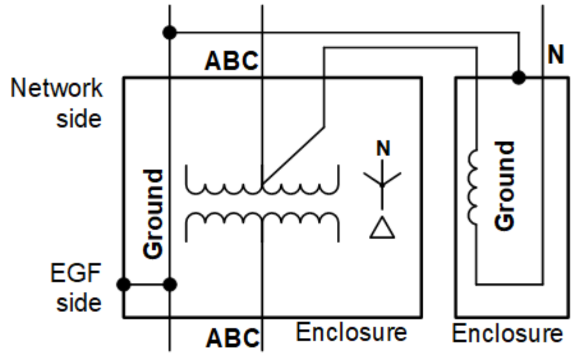
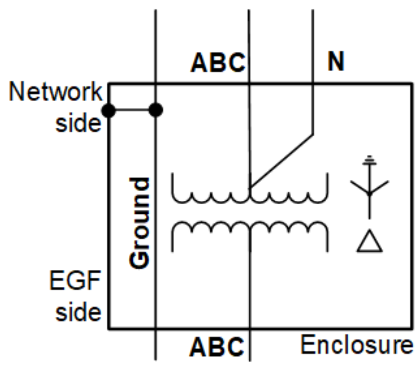


Figure 5: Y(Grounded)-Delta grounding transformer connection



(a) with inductance in the neutral



(b) without inductance

Figure 6: Y(neutral)-Delta power transformer connection

8.4 Ground impedance or resistance

The use of ground impedance or resistance at the neutral point of an EGF main transformer (Appendix B Figure 11) or the neutral point of its generators (Appendix B Figure 3) may be necessary to decrease the EGF's contribution to phase-to-ground faults on the Hydro-Québec system and comply with the protection rules listed in section 9.8.1.

The impedance or resistance value depends on the characteristics of the Hydro-Québec system and the EGF. The value must be established by the engineer appointed by the EGF owner and approved by Hydro-Québec. It must be such that the neutral-point connection at the Point of Connection remains effectively grounded.

The level of insulation and lightning impulse withstand for the impedance or resistance terminals must be the same as for the power transformer phase terminals.

8.5 Power wiring

For a phase-to-ground fault at the Point of Connection as well as any upstream point on the Hydro-Québec system side, the EGF power wiring should provide zero-sequence continuity from the Point of Connection of the EGF to the Hydro-Québec system to the generating units if the units are equipped with a neutral connection, or otherwise to the zero-sequence current source, where applicable (section 8.3), and to the metering transformers used for protection, in order to enable detection of phase-to-phase and phase-to-neutral faults, undervoltage and overvoltage by the EGF protection systems.

In other words, a device that interrupts the continuity of the neutral wire between the Point of Connection and the generating units, the zero-sequence current source, and the metering transformers used for protection is not desirable. This could occur, for example, when connecting an EGF if the facility is operated with a neutral point connection that is not effectively or solidly grounded. Such a situation would require a special study and installation of additional protection systems.

For this reason, special attention must be paid to the neutral system and to installation of the neutral wire and the equipment grounding conductor inside the EGF. Refer to the diagrams in Appendix B for details.

Hydro-Québec recommends the use of a five-conductor cable (phase A, B, C, neutral, and an equipment grounding conductor) wherever possible.

8.6 Auxiliary services

Auxiliary services required to operate the EGF must remain operational at all times and not cease to be powered following the opening of the EGF main breaker when power is maintained at the Point of Connection by Hydro-Québec.

In addition, auxiliary services must not, directly or indirectly, cause a trip during voltage and frequency variations that fall within the no-trip zone for voltage variations (section 6.4), negative-sequence voltage (section 6.5), zero-sequence voltage (section 6.6), frequency variations (section 6.7) or phase angle changes (section 6.8).

In the case of a generating station:

- As part of the Facilities Study (section 5.9), the EGF owner shall provide Hydro-Québec with the maximum power demand of auxiliary services and their expected energy consumption for each month of a typical year.
- The EGF owner must also take out an electricity supply contract in accordance with the *Terms of Service* and the *Electricity Rates.*
- If the EGF is co-located with a facility serving another purpose, such as an EGF installed in a commercial or industrial building, EGF auxiliary services must be powered from the EGF connection and used exclusively to power the EGF equipment.

8.7 Disconnectingpoint

In order to ensure the safety of metering personnel, the provisions of E.21-10, E.21-11 and F.22-01 regarding the need for upstream and downstream disconnecting points, where applicable, must be respected.[30]

In addition, the requirements of section 84 of Standard CSA C22.10*, Construction Code of Quebec - Chapter V, Electrical,* relating to disconnecting means must also be met.

To this end, a lockable disconnecting means (section 5.19), belonging to the EGF owner is required inside the EGF to enable Hydro-Québec employees to perform maintenance on the Hydro-Québec system. The disconnecting means must allow for visual or positive verification of the electrical separation at the disconnecting point.[31]

When the isolation point voltage is 750 V or less, a molded-case circuit breaker can be used as the disconnect point if:

- the circuit breaker is equipped with an indicator mechanically linked to a moving part of the electrical contacts, ensuring that the required separation has been achieved; and
- it is possible to verify the absence of voltage.

A draw-out circuit breaker can be used as a disconnect point provided Hydro-Québec employees can lock out access to the cell containing the breaker module.

In the case of EGFs with a capacity of 250 kW or greater, Hydro-Québec may require that sufficient space be provided to allow for installation of temporary grounds. In the case of a generating station connected to MV, Hydro-Québec requires that sufficient space be provided for the installation of temporary grounds.

8.8 Capacitors

In order to improve the low power factor of asynchronous generators, capacitor banks must be installed in the EGF. However, Hydro-Québec may limit the amount of reactive compensation to prevent the following phenomena:

- Rapid rise in voltage (up to 200% of nominal voltage in 1 second) that may result in ferroresonance and self-excitation following islanding on part of the Hydro-Québec system
- Overvoltages on the distribution system in steady state during low load conditions

Hydro-Québec establishes the maximum amount of compensation based on the characteristics of the EGF generators and the distribution system. Any reactive power deficit with respect to a unit power factor must be offset by installing other reactive-compensation devices at more suitable locations on the Hydro-Québec system.

[30] For an EGF connected to LV, disconnecting devices are generally required upstream and downstream of the meter for 600 V installations and for 120/240 V installations greater than 200 A. For 120/240 V installations of 200 A or less, disconnecting equipment for metering purposes is generally not required. E.21-10 and E.21-11 provide details on the requirements.
[31] For Hydro-Québec employees, the Standard D.24-20 *D.24-20 Critères de vérification des dispositifs d'isolement de source d'énergie* [criteria for checking isolating devices] provides more detail on this point.

The capacitor banks authorized for use at the EGF must be connected to each generating unit (on a proportional basis) so that a normal or forced shutdown of a generating unit would trip the associated capacitors in order to maintain an adequate compensation ratio.

8.9 MV sectionalizer

In the case of an EGF connected to the MV system, the EGF owner must adequately protect their equipment from any short circuit that may occur between the Point of Connection and the main circuit breaker. To meet this requirement, Hydro-Québec recommends, without being limited to, the use of an sectionalizer connected immediately downstream of the Point of Connection (see Figure 16 through Figure 20). The protection chosen by the power producer must be approved by Hydro-Québec.

8.10 Overvoltage protection equipment

An overvoltage protection device must be installed at the EGF upstream of any EGF equipment. If an EGF is equipped with solar panels, Hydro-Québec recommends that an overvoltage protection device be installed on the DC circuit.

The varistors on the overvoltage protection devices must be made of metallic oxide (MOV).

In the case of an EGF connected to the MV system, heavy-duty distribution-class gapless surge arresters must be installed in the EGF and upstream of any EGF equipment. Surge arresters that are not explosion-proof must be installed at least 15 metres from any Hydro-Québec facility, unless they are equipped with mechanical protection (metal enclosure or other device). The position of the surge arresters must also meet the requirements of section 4.4 (surge arresters) of standard E.21-12 *Service d'électricité en moyenne tension* [medium-voltage electrical services].

8.11 EGF main circuit breaker

The EGF must be equipped with a main circuit breaker to prevent damage to its facilities or those of Hydro-Québec. the EGF main circuit breaker must be located upstream (system side) of all generating units. Tripping of the main circuit breaker should be initiated by the various relays or protection systems. The main circuit breaker should have sufficient breaking capacity to interrupt short-circuits of any kind that occur in the EGF or on the Hydro-Québec system. For this purpose, the short-circuit current must be calculated taking into account the EGF contribution.

All generating units must be connected downstream of a single circuit breaker, used as the EGF main breaker. Opening this circuit breaker must not interrupt power to the generating station auxiliary loads or to customer loads unrelated to the EGF in the case of a Self-generation customer.

For EGFs with a capacity less than 250 kW that do not require a remote control or tripping of the EGF main circuit breaker, Hydro-Québec requires:

- a miniature circuit breaker (MCB); or
- a moulded-case circuit breaker (MCCB); or
- a low-voltage power circuit breaker (LVPCB); or
- an insulated case circuit breaker (ICCB); or;
- a medium-voltage circuit breaker (MVCB);

- installation of a warning on or immediately adjacent to the circuit breaker. Refer to section 5.20 for details on safety notice display requirements.

In the case of EGFs with a capacity of 250 kW or greater or EGFs that require a remote control or trip circuit for the EGF main circuit breaker, the circuit breaker must have separate opening and closing controls to allow for connection with the UTAPP in accordance with Standard E.12-12. Sections 9.3, 9.4 and 9.6 outline the requirements for control circuit power, closure conditioning and main circuit breaker wiring for the EGF. In addition, Hydro-Québec requires:

- a moulded box circuit breaker (MCCB) with a stored energy spring drive mechanism for opening and tripping the breaker. (Hydro-Québec will not accept a circuit breaker operated using a motor operator remote control accessory); or
- a low-voltage power circuit breaker (LVPCB); or
- an insulated case circuit breaker (ICCB); or
- a medium-voltage circuit breaker (MVCB)
- that the mechanism to manually close the EGF main circuit breaker be permanently disabled or locked out. If there is a push button on the front of the circuit breaker, it must be locked out using a method approved by Hydro-Québec. An original accessory from the manufacturer of the circuit breaker must be used for this purpose. if a lock is used to lock out the circuit breaker push button, refer to section 5.19 for more details on lockout requirements.
- that a warning be installed on the circuit breaker or its control box in the case of a MV circuit breaker. Refer to section 5.20 for details on safety display requirements.
- that the loss of power to protective relays, circuits used to protect the Hydro-Québec system, or the EGF main circuit breaker when power is required, results in the immediate opening of the EGF main circuit breaker.

8.12 Power transformers

Hydro-Québec recommends that EGFs of less than 250 kW be connected without installing a power transformer in order to ensure zero-sequence continuity from the EGF Point of Connection with the Hydro-Québec system to the generating units. This allows the detection of phase-to-phase and phase-to-neutral faults, undervoltages and overvoltages by the EGF protection systems.

8.12.1 Specifications

Transformer characteristics must meet the specifications of CAN/CSA C2-M91, CAN/CSA-C88-M90, CAN/CSA-C9-M1981 and CSA C22.2 No. 47, depending on the type of equipment.

Hydro-Québec recommends the use of transformers with terminals that are compatible with the voltage ranges set out in the provisions of Standard C.21.1 *Canadian Electrical Code* on acceptable voltage limits.

For three-phase systems with Y-Y windings, Hydro-Québec requires the use of three single-phase transformers or a three-phase four-column, five-column or shell-type transformer (Figure 7). Hydro-Québec recommends the use of a five-column transformer. The use of a three-phase transformer with Y-Y windings built on a three-legged core is prohibited.

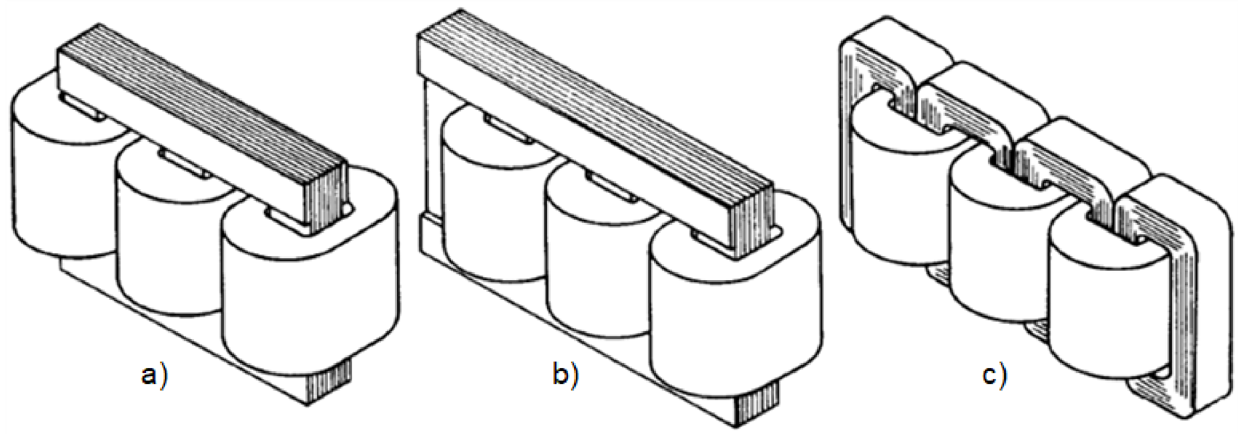


Figure 7: Three-phase transformer construction types;
a) 3 columns, b) 4 columns, c) shielded [32]

When a three-phase transformer with Y-Y windings is used, the transformer's name plate must show the type of transformer core construction to allow Hydro-Québec to verify this during testing (section 5.14). The nameplate should indicate "4 columns", "5 columns" or "shielded."

When a three-phase transformer used to connect an EGF requires the neutral point of a star or zigzag winding to be connected to ground and that winding is on the Hydro-Québec system side rather than the load side:

- Hydro-Québec requires that the transformer be equipped with a connection point to the transformer's neutral terminal so that the neutral-to-ground connection can be made upon installation rather than in the factory or that a neutral resistor or inductor can be installed as required.
- The level of insulation and lightning impulse withstand performance for the neutral terminal must be the same as for the phase terminals.

8.12.2 Connection types

With the exception of an isolation transformer integrated with an inverter, any power transformer used between the Point of Connection and metering point of the EGF's protection functions must have its windings connected in such a way that the protection system can detect all types of short-circuit that may occur on the distribution system or in the EGF.

For an EGF connected to LV, to ensure zero-sequence continuity from the EGF Point of Connection to the generating units, Hydro-Québec recommends a Y(neutral) (system side) – Y(Grounded) (EGF side) transformer connection for all transformers installed between the EGF Point of Connection and the generating units, as this ensures the passage of zero-sequence current. The Figure 8 and Figure 9 below illustrate how to obtain a Y(neutral)–Y(Grounded) connection using three single-phase transformers or a three-phase transformer.

[32] IEEE C57.105, *Guide for Application of Transformer Connections in three-phase Distribution Systems*, 2008.

However, the EGF owner has the option of proposing an alternate connection to meet specific needs. In this situation, Hydro-Québec must conduct a study to determine whether the proposal is acceptable from a system perspective.[33]

In the case of an EGF connected to MV, the connection of the power transformer and the associated zero-sequence current source, where applicable (section 8.3), must ensure a neutral system which is effectively grounded at the Point of Connection.

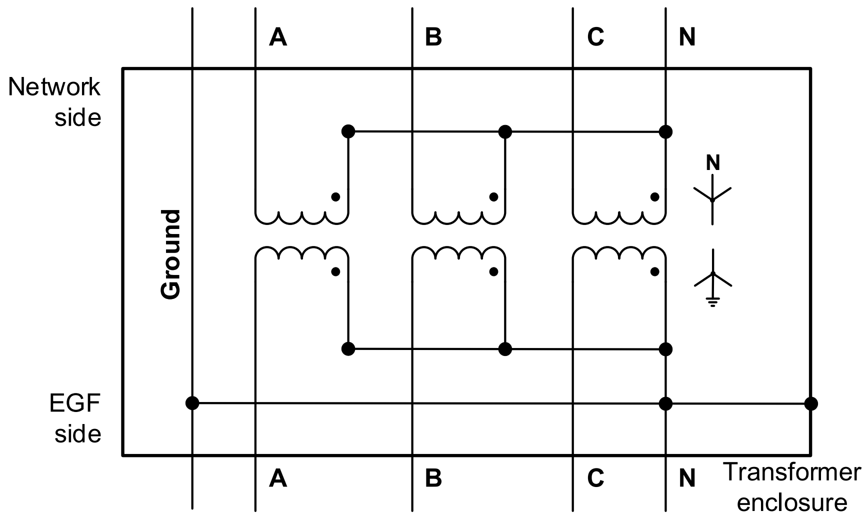


Figure 8: Connection of three single-phase transformers for three-phase Y(neutral)–Y(Grounded) use

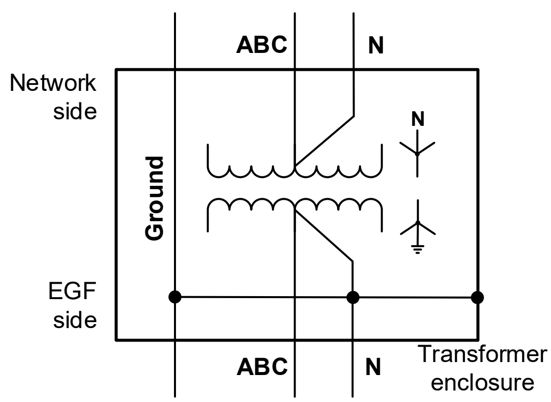


Figure 9: Connection of a three-phase Y(neutral)-Y(Grounded) transformer

33 For Hydro-Québec employees, Technical Bulletin 30332-18-006-B *Raccordement des transformateurs pour les clients moyenne tension (CMT) et les installations de production d'électricité (IPÉ)* [transformer connections for medium voltage customer (MVC) and electricity generating facilities (EGFs)] provides more details on this point.

8.12.3 Power transformer inrush current

The EGF must be designed in such as way that its power transformers can be energized without tripping Hydro-Québec line protection, while respecting the requirements for voltage fluctuations (section 6.1). This requirement must be demonstrated in the Facilities Study (section 5.9).

If inrush current on the power transformers is too high to be magnetized directly by the Hydro-Québec system, i.e., energization of the transformers would cause Hydro-Québec's line protection to trip or engender voltage variations greater than the allowable limits (section 6.1), a mitigation measure must be implemented to comply with the voltage fluctuation requirement (section 6.1). The following methods are proposed by Hydro-Québec:

- Magnetization of the power transformers is performed by the EGF generating units. In this case, synchronization to the distribution system must be performed using a generator synchronism check system (function 25) (section 7.1.2).
- In the case of a generating station with multiple units, several power transformers are used, and they are magnetized in sequence using motorized switches to decrease the amplitude of the inrush current.
- Resistors or pre-insertion inductors are used to limit the magnetizing inrush current.
- A control unit controls the phase-by-phase closure of the EGF main circuit breaker to optimize the timing of the closure of each phase with the angle of the remanent flux present in the transformer. This reduces the inrush current by limiting the difference in angle between the remanent flux in the transformer and the voltage phase angle at the selected time of closing on the waveform.
- Magnetization of the power transformers is carried out using an auxiliary transformer.
- The use of a power transformer with low flux density.

The performance of the chosen mitigant must be validated by calculations and simulations in the Facilities Study (section 5.9) and by means of tests (section 5.14).

8.12.4 LV connection without transformer

The use of a transformer between the Point of Connection of an EGF connected to the LV system and the EGF generating units is optional if the nominal group voltage permits direct connection. In the case of generators, the neutral system at the Point of Connection must be compliant with the system agreed upon with Hydro-Québec (section 5.3). However, the EGF design must account for the fact that a facility without a coupling transformer may have the following drawbacks:

- Generating equipment would not benefit from the protection provided by the transformer during voltage surges due to lightning.
- In the event of a short circuit, there may be overcurrent in the generator winding (welding of plates and destruction of the generator).
- There would no longer be a 3rd harmonic filter (assuming a delta connection on the secondary side).
- The EGF should still meet the EGF behaviour requirements (section 7), considering the normal operating voltage limits of the distribution system.

8.12.5 Connecting an IBR

In the case of an EGF using IBR, Hydro-Québec requires that the power transformer have double electrostatic shielding. The use of a transformer with a K-factor of 4 or more is recommended, particularly to avoid heating the transformer by harmonic current circulation. A similar effect can also be achieved by oversizing the transformer[34].

The connection of some inverter models requires galvanic isolation between the inverter and the electrical system. The engineer appointed by the EGF owner must verify the power transformer characteristics required by the inverter. If the inverter requires galvanic isolation, a Y(Neutral)-Y(Grounded) transformer cannot be used for the connection.

8.13 IBRs

Hydro-Québec requires the use of certified inverters (section 8.13.1). In addition, Hydro-Québec recommends the use of an inverter that does not require galvanic isolation (section 8.12.5) and that has a terminal for the neutral wire (section 8.13.2). This allows the use of a Y(Neutral)-Y(Grounded) power transformer (section 8.12.2) and 5-conductor power wiring (section 8.5).

8.13.1 Certification

The inverter must be certified to UL1741-SB or later to ensure advanced system support functions, interoperability features and overvoltage protection during a phase-to-ground fault or a load rejection.

The inverter must have been tested per section SB4.3.5.17 of Standard UL1741-SB. The test results of SB4.3.5.17 *Limitation of overvoltage contribution* must demonstrate compliance with the criteria of IEEE 1547-2018 section 7.4 *Limitation of overvoltage contribution* for an effectively grounded system. For example, tests must have been performed demonstrating that for an overvoltage of 138% or more, the inverter stops injecting current in less than 1 cycle.

The applicable inverter requirements are those of Category B and III of Standard IEEE 1547-2018. Category B specifies the performance criteria required for voltage regulation during a high-level penetration of distributed energy resources. Category III specifies ride-through criteria for undervoltage, overvoltage and frequency variations.

An EGF using IBRs whose generating units have a combined rated capacity of 250 kW or more must use inverters that have been recently certified to IEC 62786-1:2023 or higher by an independent laboratory recognized by the Standards Council of Canada.

8.13.2 Connection of the neutral wire to the inverter

The inverter's electrical connection to the Hydro-Québec system must allow the protection functions included in the inverter to detect phase-to-phase and phase-to-neutral faults, undervoltages and overvoltages on the Hydro-Québec system and inside the EGF.

For this reason, Hydro-Québec recommends that the inverter be equipped with a neutral wire terminal. This terminal must have been provided by the manufacturer for this purpose and must be clearly identified.

[34] IEEE C57.110, *Recommended Practice for Establishing Liquid-Immersed and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsinusoidal Load Currents*, 2018.

If the inverter does not have a terminal for the neutral wire, an external protection system must be installed to allow the EGF to detect phase-to-neutral faults and under- and overvoltages. Refer to Figure 5and Figure 6 in Appendix B for more details.

8.13.3 Exception for new industrial processes and testbeds

In the specific case where a certified inverter is not commercially available for a particular application such as a new industrial process or test bed, Hydro-Québec may accept the use of an inverter that is not certified, if it is demonstrated that the EGF will meet all the requirements of this standard.

In the case of EGFs with a capacity of 250 kW or greater that use an uncertified inverter, Hydro-Québec may require the EGF owner to provide the data as well as a detailed numerical model(s) of the EGF required to conduct dynamic behaviour studies. The EGF owner may also be required to provide the information and data required to perform electromagnetic transient (EMT) studies by submitting a transient numerical model. Detailed requirements are specified in *Exigences techniques de raccordement de centrales au réseau de transport d'Hydro-Québec* [technical requirements for the interconnection of generating stations to the Hydro-Québec transmission system].

8.13.4 Protection functions of a certified inverter

An EGF that:

- has a certified inverter as a generating unit (section 8.13.1)
- has an inverter with a neutral wire terminal (section 8.13.2)
- has five-conductor wiring (phase A, B, C, neutral and equipment grounding conductor) (section 8.5)
- does not have a zero-sequence current source (section 8.3)
- has a Y(neutral)(system side)–Y(Grounded)(EGF side) transformer connection (section 8.12)

is considered compliant with the protection requirements of sections 9.1.2 and 9.1.6 (backup protection mechanism and permissive for closing the EGF main breaker) of this standard when the settings required by Hydro-Québec are used.

In addition, when an EGF Point of Connection to the Hydro-Québec system is three-phase, the EGF must trip all three phases if one of the phases reaches the voltage trip threshold.[35]

8.13.5 Connection to EGF protection

The inverter of an IBR must be able to send the trip command to the EGF protection system in such a way as to open the EGF main circuit breaker when the inverter protection circuits trigger a trip. This is to ensure trip command lockout (section 9.5) and ensure that a pending UTAPP lockout command can effectively lock the EGF main circuit breaker in the open position following an inverter trip (Appendix B Figure 22), so as to prevent the EGF main breaker from closing when required by the DCC.

[35] This requirement is repeated in note 1 under Table 12. For this reason, if three separate single-phase inverters are used instead of a three-phase inverter, unless the single-phase inverters are certified and come with the manufacturer's instructions for a three-phase installation configuration using three single-phase inverters, a protection relay and a circuit breaker will be required to ensure that all three inverters trip in the event of a voltage excursion on one of the phases.

In this situation, the connection circuits used to transmit inverter commands from an IBR inverter to the EGF protection system are considered as being used to protect the Hydro-Québec system, and all related requirements of section 9 are applicable.

8.13.6 Multimode inverter

In order to ensure the safety of its employees and the public, Hydro-Québec does not allow its system to be connected to standalone inverters, also known as grid forming.

However, an EGF can be used as a backup power source under certain conditions (section 12).

In order to ensure the safety of Hydro-Québec personnel and the public, if a multimode inverter is to be connected to the Hydro-Québec system and it has only one terminal,[36] Hydro-Québec must ensure that the unit will never operate in standalone mode. To this end, Hydro-Québec sets the following conditions:

- The inverter must never be used in standalone, grid-forming mode.
- The ability to operate in standalone mode must be permanently disabled by means of a software or hardware configuration.
- If a software configuration is used to disable the standalone mode, it must be permanently protected from any modifications and made inaccessible to the end user. Protection using a password that is inaccessible to the end user may be used for this purpose. In this case, the manufacturer's original password must have been changed and the new password must be robust.
- Commissioning tests showing that the inverter will not start in standalone mode in the event of power loss must be performed.
- A permanent label must be affixed to the inverter indicating that operation in standalone or grid-forming mode is prohibited (section 5.20) (Appendix E Figure 11).
- A signed letter from the engineer appointed by the EGF owner who performed the commissioning tests must be sent to Hydro-Québec stating that:
  - The electrical facility installation is not designed to allow the inverter to be used in standalone mode.
  - The ability to operate the inverter in standalone mode has been permanently disabled by means of a software or hardware configuration that cannot be altered by the system user.
  - Commissioning tests have shown that the inverter will not start in standalone mode in case of power loss.
  - A permanent label has been placed on the inverter indicating that it is forbidden to operate it in standalone mode.

[36] That is, the inverter does not have a clearly identified terminal for connecting to the distribution system (which cannot operate in standalone mode) and a second clearly identified terminal for connecting customer critical loads (which can operate in standalone mode without being connected to the distribution system).

8.14 Electrical protection of the EGF

The EGF owner is responsible for protecting their equipment properly. It must ensure that the equipment is protected under normal and marginal power system operating conditions (section 4.1). It must ensure that sufficient protection systems are available and capable of performing suitable functions to protect the EGF from any type of event that may occur on the Hydro-Québec system, including short-circuits, phase losses, overcurrents, overvoltages, undervoltages, over-frequencies and under-frequencies. Certain operating conditions on the Hydro-Québec system and at power producer facilities may cause overvoltages or resonance phenomena (e.g. machine auto-excitation, ferroresonance, and subsynchronous resonance when series compensation is used on the grid). In order to control the effects of such events on its system, Hydro-Québec may impose additional requirements or restrictions applicable to certain operating modes at power producer facilities.

The EGF owner must also adequately protect its equipment from potential load and voltage unbalances resulting from certain operating conditions. Such unbalances may cause the flow of zero- and negative-sequence current, thus causing generator overheating and potential damage.

EGF protection functions must be designed and set in such a way so as to not to be activated within the no-trip zone for voltage variations (section 6.4), negative-sequence voltage (section 6.5), zero-sequence voltage (section 6.6), frequency variations (section 6.7) and phase angle changes (section 6.8). They must ensure the safety of the public and Hydro-Québec personnel without tripping during transient events on the Hydro-Québec system.

9 Requirements for the protection of the Hydro-Québec system

This section covers Hydro-Québec requirements for protection systems installed in an EGF to ensure protection of the Hydro-Québec system. The EGF must meet these requirements and the EGF design must include the various protective devices required.

Systems to protect the Hydro-Québec system must control tripping of the EGF main circuit breaker in the event of a short circuit, phase loss or electrical disturbance on the Hydro-Québec system and secondly, in the event of a short-circuit inside the EGF. Tripping of the main circuit breaker by Hydro-Québec system protection is not to be used for any other purpose.

For information purposes, Appendix B shows typical facility connection, control and protection diagrams.

9.1 Types of protection

The minimum protection functions required by Hydro-Québec to protect its system are listed below. They are designed to detect all types of faults and disturbances that may affect the Hydro-Québec system.

9.1.1 Primary or fault protection

Primary protection consists of line protection. It is used to detect short-circuits on the Hydro-Québec distribution system. Primary protection consists of the following:

- Instantaneous and time-delayed phase overcurrent protection (function 50/51)
- Instantaneous and time-delayed neutral overcurrent protection (function 50N/51N)
- Instantaneous and time-delayed fast neutral overcurrent protection (function 50NR/51INR)
- Instantaneous phase current imbalance protection (function 50Q)

Instantaneous, time-delayed phase overcurrent protection (function 50/51) is required in an EGF using a generator.

Instantaneous and time-delayed neutral overcurrent protection (function 50N/51N) is required in an EGF equipped with a zero-sequence current source (section 8.3) such as a grounding transformer or generator with Y windings and a neutral point connection to the neutral conductor.

Instantaneous and time-delayed fast neutral overcurrent protection (function 50NR/51NR) is required in an EGF with a zero-sequence current source (section 8.3) and a UTAPP (section 5.2). In this case, the fast neutral overcurrent protection (function 50NR/51NR) is activated when the UTAPP lock is activated.

Instantaneous phase current imbalance protection (function 50Q) is required in an EGF using IEC 62786-1 certified IBRs.

However, the following situations could render overcurrent protection ineffective and unacceptable:

- The EGF consists of several generating units, one or more of which may be out of service (the EGF's contribution to short-circuits may be insufficient to meet the rules specified in section 9.8.1).
- The technology used does not produce enough overcurrent to meet the rules specified in section 9.8.1 and the negative-sequence contribution is insufficient to use current imbalance protection (function 50Q) as a replacement.
- The EGF's fault contribution is too significant and is degrading fuse coordination on the Hydro-Québec system.

In these cases, voltage-restrained overcurrent protection (51V function) combined with neutral overcurrent protection (function 50N/51N) could be used.

When the EGF contribution to a phase-to-phase fault is less than 8 amps per phase at MV[37] for a solid two-phase fault at the Point of Connection,[38] and the contribution to a phase-to-ground fault is less than 5 amps at MV[39] for a solid phase-to-ground fault at the Point of Connection,[38] it is not necessary to consider the impact of the generating station's fault contribution on Hydro-Québec's distribution system.[40] Thus, when a zero-sequence current source is used (section 8.3), it may be advantageous to size it so as to limit the contribution to a 5 amp phase-to-ground fault at MV.

As a last resort, Hydro-Québec may accept that backup protection serves as primary protection (solution generally accepted for IBRs and asynchronous generators).

[37] The 8 A threshold was selected because the lowest phase protection setting used in Hydro-Québec's MV circuit breakers is 160 A. Considering that the measurement error for current transformers used for protection is 5%, a decrease in phase current measured by the MV line protection of 8 A (due to masking by the EGF's contribution) is equivalent to the margin of measurement error.
[38] or the first MV busbar upstream of the connection point for an EGF connected to LV.
[39] The 5 A threshold was selected because the lowest neutral protection setting used in the MV line feed circuit breakers at Hydro-Québec's distribution substations is 100 A. Considering that the measurement error for current transformers used for protection is 5%, a decrease in neutral current measured by the MV line protection of 5 A (due to masking by the EGF's contribution) is equivalent to the margin of measurement error.
[40] For Hydro-Québec employees, the fact that an EGF has a short circuit contribution of less than 8 A and 5 A at MV eliminates the need to conduct a protection coordination study as described in section 9.3.5 of Standard E.12-02.

9.1.2 Backup or anti-islanding protection

These protections mainly detect situations that may generate EGF islanding following accidental opening or tripping of equipment on the Hydro-Québec system. Backup protection consists of the following protection functions:

- Three-phase undervoltage and overvoltage protection (functions 27 and 59)
- Underfrequency and overfrequency protection (functions 81U and 81O)

Backup protection must be three-phase when the Point of Connection to the Hydro-Québec system is three-phase, or single-phase when the Point of Connection to the Hydro-Québec system is single-phase.

In the case of a three-phase installation, the backup protection must be able to effectively detect a phase-to-ground fault or the loss of a single phase on the MV distribution system. For this reason, if the zero-sequence continuity from the EGF's Point of Connection with the Hydro-Québec system to the generating units has been broken by the presence of a delta winding transformer or by the power wiring (section 8.5), a backup protection metering point should be installed at a point where zero-sequence continuity to the EGF Point of Connection with the Hydro-Québec system has been maintained (for example, upstream of the power transformer with delta winding).

For IBRs, active anti-islanding protection may be approved in addition to the above protections.

Islanding must be detected by the backup protection within two seconds or less. The settings in sections 9.8.3 and 9.8.4 make it possible to achieve this objective when the EGF behaviour requirements in section 7 are met.

Backup protection also serves as a rear guard against short-circuits on the Hydro-Québec system.

9.1.3 Protection to ensure minimum load

Hydro-Québec recommends that Self-generation customers use minimum load protection in order to meet the load/generation ratios presented in Table 11 so as to mitigate the risk of extended unintentional islanding and out-of-sync reclosing. This protection makes it possible to minimize the impact of connecting output from a generating facility to the Hydro-Québec system and reduces connection costs and construction time.

This can be beneficial in cases where a Self-generation customer's electrical load consistently exceeds their electricity output. It can also be attractive for customers who wish to reduce their electricity consumption during peak periods.

Method A.5-10 *Application de la norme E.12-01 au raccordement d'une IPE triphasée* [application of Standard E.12-01 to the connection of a three-phase EGF] provides details on how to use protection to limit injection of power in an EGF with IBRs and an electrical storage system.

Minimum load protection consists of the following functions:

- Directional power protection (function 32) set toward the customer.

Directional power protection (function 32) must be set in the direction of the customer facility so that power at the Point of Connection always flows toward the Self-generation customer facility (Figure 10 and Figure 11).

A prior agreement must be reached between the Self-generation customer and Hydro-Québec to determine minimum power consumption at the Point of Connection. When power consumption at the customer facility falls below this threshold value, the minimum load protection must be designed so as to trip the EGF main circuit breaker. Figure 11 illustrates the concept of tripping directional power protection to ensure minimum power consumption.

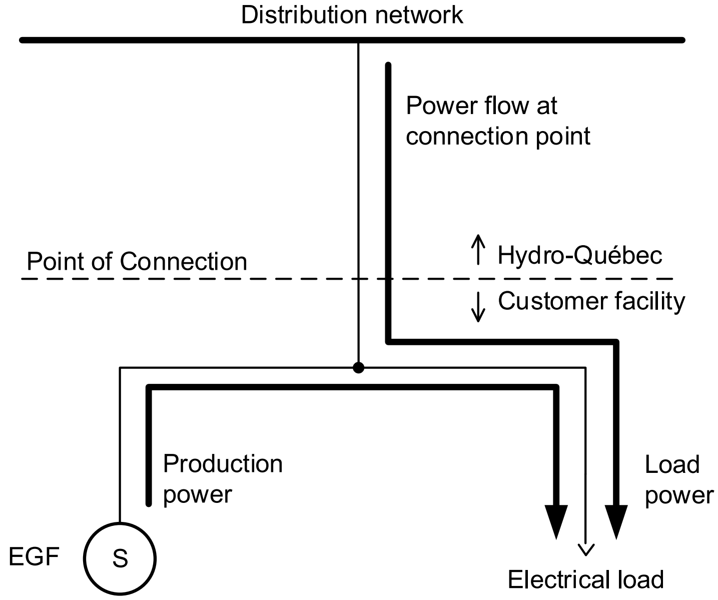


Figure 10: Active power flow (kW) at the Point of Connection of a Self-generation customer facility equipped with minimum load protection

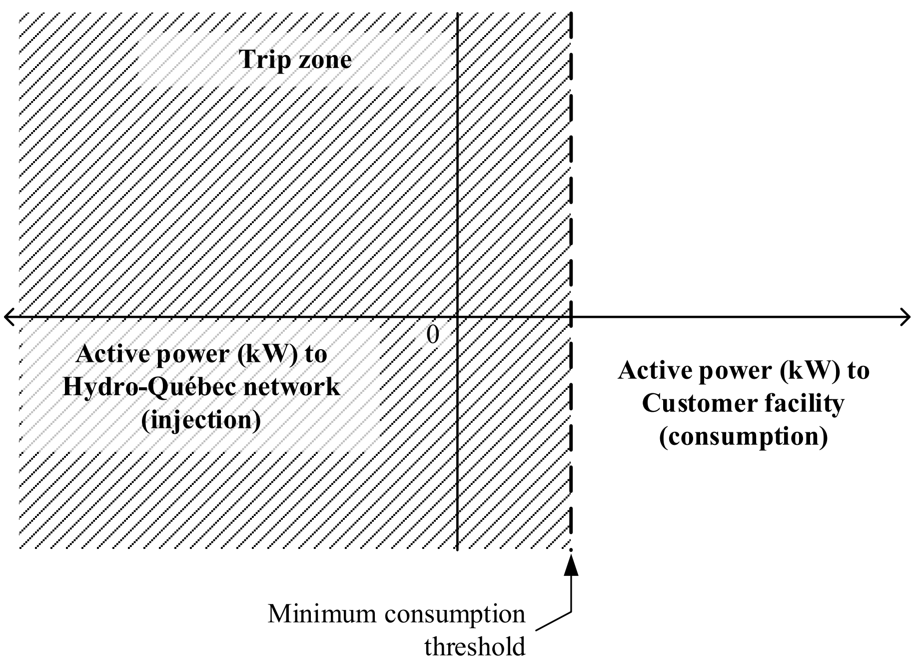


Figure 11: Concept of tripping protection to ensure minimum load in a Self-generation customer facility

This protection is intended to simplify the operation of an EGF with an installed capacity of 250 kW or more where the EGF owner does not wish to inject power into the Hydro-Québec distribution system.[41] Implementing minimum load protection exempts the EGF from application of section 5.16 of the guideline concerning operation of an EGF with an installed capacity of 250 kW or more, including installation of a UTAPP.

This protection is also intended to simplify interconnection and limit the impact of an EGF on the Hydro-Québec distribution system by ensuring the Self-generation customer facility has a sufficient load to reduce the risk of extended unintentional islanding and out-of-sync reset. This can help reduce the complexity of the System Impact Study[42] described in the section 5.8 and reduce the number of system modifications required to integrate an EGF.

When minimum load protection is used to ensure the EGF will be overloaded as a result of decoupling from the distribution system (in islanding condition), the power consumed by the electrical load at the customer facility must be equal to or greater than the value required to achieve the load/generation ratio defined in Table 11. The load/generation ratio is defined by Equation 4.

Table 11: Minimum EGF load/generation ratio to mitigate the risk of extended unintentional islanding and out-of-sync reclosing

Type of EGF generator	P_{load} / $P_{EGF\ name}$
IBR or dual winding asynchronous generator	1.1
Synchronous inertia ≤ 2 seconds	1.5
Synchronous inertia > 2 seconds	2

$$Load/generation\ ratio\ \frac{P_{load}}{P_{EGF\ name}}$$

P_{load} : Customer facility load (kW)[43]
$P_{EGF\ name}$: Rated capacity of the EGF (kW)

Equation 4: Calculating the load/generation ratio of an EGF

If the load/generation ratio is below the limits specified in Table 11, there is a risk of extended unintentional islanding and out-of-sync reclosing, and the System Impact Study (section 5.8) will need to determine the mitigation measures required to mitigate these risks. In this case, minimum load protection can still be used, but with a different threshold.[44]

[41] This approach is equivalent to the old “Type 1” approach in E.12-06:2007 for directional power protection settings.
[42] For Hydro-Québec employees, the presence of minimum load protection as per the criteria in Table 11 may eliminate the need to implement measures to mitigate the risk of extended unintentional islanding or out-of-sync reclosing, as described in section 9.1 of Standard E.12-02.
[43] The customer facility’s minimum load must be used in the calculation if the customer does not have a load and generation control system that limits output when load is insufficient.
[44] This approach is equivalent to the former "Type 2" approach in E.12-06:2007 for directional power protection settings.

For EGFs using IBRs, it may be preferable to maintain a load/generation ratio of 1.5 or higher as specified in section 5.3.2 and Appendix D to avoid having to produce a neutral system study and install a zero-sequence current source in the EGF, as the case may be.

During normal operation, in order to avoid reaching the directional protection trip threshold, it is advisable to reduce power generation in anticipation of a decrease in power consumption. The Self-generation customer must therefore have a good knowledge of its facility's power consumption as well as sufficient control over production power. An energy management system can be installed by the EGF owner to coordinate power generation with power load and ensure minimum load is maintained.

Directional power protection may be sensitive to load variations within the Self-generation customer facility and to normal voltage variations on the distribution system. Therefore, the protection required by the EGF must never cause unwarranted tripping due to facility load variations or normal voltage variations on the distribution system. In this situation, mitigation may be required.

Protection to ensure minimum load must be three-phase when the Point of Connection to the Hydro-Québec system is three-phase or one-phase when the Point of Connection to the Hydro-Québec system is one-phase.

The metering point for minimum load protection must be upstream of the load Point of Connection in the customer facility (see Figure 21 in Appendix B).

Activation of directional power protection (function 32) must trigger the opening of the EGF main circuit breaker. In the case of an EGF installed at a Self-generation customer's premises, activation of directional power protection must not result in the interruption of the power supply to the customer facility load.

When implementing directional power protection (function 32), the engineer appointed by the EGF owner must ensure that the accuracy of the chain of protection (metering, relay and wiring) is sufficient to allow the relay to operate properly according to the chosen setting. If the accuracy of the chain of protection is not adequate, corrective measures should be implemented such as the use of metering class transformers or a billing relay for power metering.

In order to prevent directional power protection from tripping at EGF startup if customer load is insufficient to ensure the minimum load required, Hydro-Québec recommends implementing mitigation measures such as additional directional power protection (function 32) used as permissive for closing the EGF main breaker.

9.1.4 Protection to limit injection of power

The owner of an EGF may choose to install protection to limit injection of power. This may be beneficial in the case of a Self-generation customer.

Method A.5-10 *Application de la norme E.12-01 au raccordement d'une IPE triphasée* [application of E.12-01 to connection of a three-phase EGF] details how to use the protection to limit injection of power in the case of an EGF using IBRs and an electrical storage system.

Protection to limit injection of power consists of the following:

- Directional power protection (function 32) set toward the Hydro-Québec system

Directional power protection (function 32) must be set toward the Hydro-Québec system, that is, power at the point of connection must flow to the Hydro-Québec system within the 200 kW limit (Figure 12 and Figure 13).

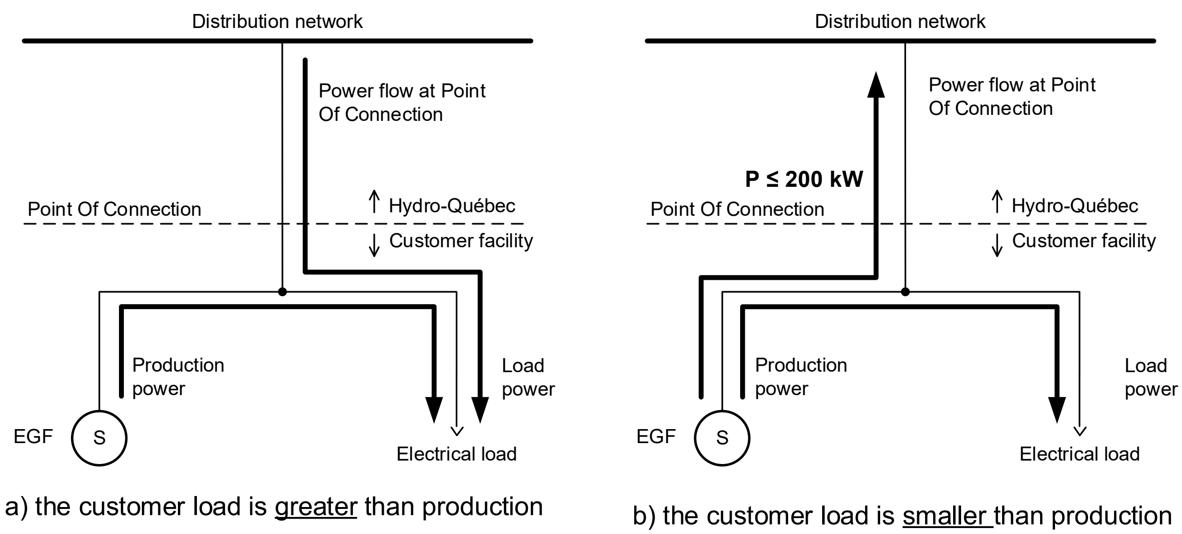


Figure 12: Active power flow (kW) at the Point of Connection of a Self-generation customer facility with protection to limit injection of power

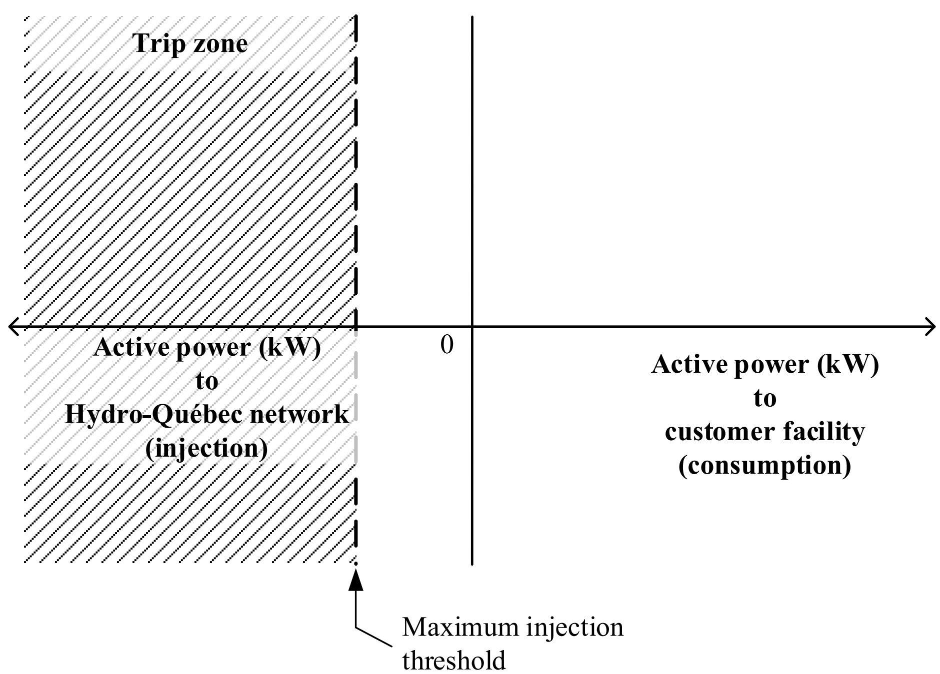


Figure 13: Concept of protective tripping to limit injection of power in the Self-generation customer facility

This protection is intended to simplify the operation of an EGF with an installed capacity of 250 kW or greater for which the EGF owner does not wish to inject more than 200 kW into the Hydro-Québec distribution system.[45] Implementation of protection to limit injection of power exempts the EGF from the application of section 5.16 of the guideline with an installed capacity of 250 kW or more, including an exemption from installing a UTAPP.

The impact of connecting an EGF equipped with protection to limit injection of power on the Hydro-Québec system is greater than that of an EGF equipped with minimum load protection. There is a risk of extended unintentional islanding and out-of-sync reclosing, and the System Impact Study (section 5.8) will have to determine the mitigation measures required to mitigate these risks.

During normal operation, in order to avoid reaching the directional protection trip threshold, it is advisable to reduce power generation in anticipation of a decrease in power consumption. The Self-generation customer must therefore have a good knowledge of its facility's power consumption as well as sufficient control over production power. An energy management system can be installed by the EGF owner to coordinate power generation with power load and ensure minimum load is maintained.

Directional power protection may be sensitive to load variations within the Self-generation customer facility and to normal voltage variations on the distribution system. Therefore, the protection required by the EGF must never cause unwarranted tripping due to facility load variations or normal voltage variations on the distribution system.

The protection to limit injection of power must be three-phase when the Point of Connection to the Hydro-Québec system is three-phase, or one-phase when the Point of Connection to the Hydro-Québec system is one-phase.

The metering point for the protection to limit injection of power must be upstream of the load Point of Connection in the customer installation (see Figure 21 in Appendix B).

Directional power protection (function 32) must trigger the opening of the EGF main circuit breaker. In the case of an EGF installed at a Self-generation customer's premises, activation of directional power protection must not result in the interruption of the power supply to the customer facility load.

When implementing directional power protection (function 32), the engineer appointed by the EGF owner must ensure that the accuracy of the chain of protection (metering, relay and wiring) is sufficient to allow the relay to operate properly according to the chosen setting. If the accuracy of the chain of protection is not adequate, corrective measures should be implemented such as the use of metering class transformers or a billing relay for power metering.

9.1.5 Protection to limit contribution to overvoltage

For EGFs with a capacity of less than 250 kW using IBRs and a UL1741-SB certified inverter, the inverter must comply with section 7.4 *Limitation of overvoltage contribution* of Standard IEEE 1547-2018, which is required for UL1741-SB certification. In this situation, Hydro-Québec requires that overvoltage protection in the event of a phase-to-ground fault or load rejection be activated. This protection must immediately stop the inverter from injecting power.

[45] This approach is similar to the old "Type 3" approach in E.12-06:2007 for directional power protection settings.

In the case of EGFs with a capacity of 250 kW or greater using IBRs and an IEC 62786-1 certified inverter, Hydro-Québec requires that overvoltage protection in the event of a phase-to-ground fault or load rejection be disabled. In this case, the inserter's reactive current contribution during system events, described in section 4.7.6 *Additional reactive current requirements on generating plants*, must be used to limit the contribution to overvoltages. The neutral system study will need to confirm the effectiveness of the inverter's reactive current contribution in mitigating temporary overvoltages.

9.1.6 EGF main circuit breaker closing permissive

This protection function is used to ensure that the EGF main circuit breaker can only be closed if EGF startup conditions are met (section 7.1.1). The EGF main circuit breaker closing permissive must be wired in series with the EGF main circuit breaker closing circuit (section 9.4).

The EGF main circuit breaker closing permissive consists of the following:

- a three-phase under- and overvoltage element (functions 27 and 59) associated with a 5-minute timer (function 62)
- a sub-frequency and overfrequency element (functions 81U and 81O)
- the absence of any trip command
- if minimum load protection is used in the EGF (section 9.1.3), the EGF owner may choose to add a directional power element (function 32) to ensure that minimum load is present before the EGF is started.

9.1.7 Breaker failure protection

An EGF greater than 5 MW must be equipped with main circuit breaker fault protection (function 50BF). This protection must monitor the operation of the EGF main circuit breaker and, if it fails, control the opening of all generating unit breakers simultaneously.

One approved method is to monitor a position contact (52A or 52B) and current flow through the circuit breaker. If the status of the position contact has not changed after the maximum opening delay and the current is still flowing, the circuit breaker is declared faulty. The use of logic to control a second attempt to open the breaker is permitted, provided that it acts before the maximum opening delay expires.

The main circuit breaker failure shall be reported to the UTAPP via the alarm signal.

9.1.8 Additional protections at the EGF

In some cases, the following protections may be required by Hydro-Québec to ensure the protection of its system:

- Remote tripping of the EGF main circuit breaker
- Line protection with telecommunications
- Any other protection Hydro-Québec deems necessary

EGFs with a capacity of 1 MW or greater must also comply with the remote tripping requirements in section 8.4.3.3*Exigences techniques de raccordement de centrales au réseau de transport d'Hydro-Québec* [technical requirements for the interconnection of generating stations to the Hydro-Québec transmission system].

9.2 Multifunction protective relays

Relays used to protect the Hydro-Québec system must be physically, functionally and electrically distinct from those used to protect the EGF. They cannot be used for any purpose other than the protection of Hydro-Québec's system. However, it is acceptable for these relays to transmit control or alarm signals to the rest of the facility, so long as this does not require the addition of additional logic in the relay.

Relay models that can be used to protect the Hydro-Québec system are found in a list available on the Hydro-Québec website. They are qualified by Hydro-Québec and have been selected based on the performance required to ensure power system protection. Standard E.12-09, *Exigences relatives à la qualification des équipements de protection utilisés pour le raccordement de la production décentralisée sur le réseau de distribution d'Hydro-Québec* [requirements regarding the qualification of protection equipment used to connect distributed generation to the Hydro-Québec distribution system] has been used to qualify relays on this list.

For EGFs with a capacity of 250 kW or greater, primary and backup protection must be provide by separate relays to ensure a degree of redundancy. The use of multifunction relays may be approved by Hydro-Québec, provided that more than one relay is used to ensure redundancy. An approved method is to use two identical multifunction relays within which all protection functions are implemented, which is equivalent to implementing all protection functions in duplicate.

If a protective relay has a watchdog function monitoring relay operational status, the failure signal must be reported to UTAPP as appropriate (section 10.5); this function must be used under the trip conditions of the EGF main circuit breaker as per the following logic:

- When a single relay is used for a protection function required by Hydro-Québec, a watchdog malfunction signal for the relay must trip the EGF main circuit breaker.
- When two independent relays are used for the same protection function required by Hydro-Québec, a signal from one of the relays may transmit an alarm without tripping the EGF main circuit breaker. However, a malfunction signal from both independent relays must trip the EGF main breaker without delay.

9.3 Power supplies used for protection

The direct-current or alternating-current supply used for the protection of the Hydro-Québec system must have a minimum backup time of 15 minutes. To this end, a standalone power supply dedicated to protecting the Hydro-Québec system must be used. Direct-current or alternating-current power supplies used for the protection of the Hydro-Québec system are not to be used for any purpose other than the protection of the Hydro-Québec system.

9.3.1 Multifunction protective relays

Direct-current relay power must be supplied by auxiliary service consisting of storage batteries connected in parallel to a charger. Use of a static uninterruptible power supply (UPS) is allowed for supplying alternating-current relays.

Hydro-Québec recommends the use of relays powered by direct current supplied by auxiliary service consisting of storage batteries connected in parallel to a charge. This is mandatory for EGFs with a capacity greater than 5 MW.

9.3.2 UTAPP

Power for the UTAPP and its cellular modem, signal amplifiers/converters, and other required accessories must be supplied by auxiliary service consisting of storage batteries connected in parallel to a charger.

9.3.3 Circuits used to protect the Hydro-Québec system

These circuits include, but are not limited to, power and control circuits for multifunction protective relays, auxiliary and interposition relays, and control circuits for opening and closing circuit breakers for system protection.

9.3.4 Monitoring of circuits used to protect the Hydro-Québec system

When a direct-current power supply is used to protect the Hydro-Québec system, continuous battery monitoring must be performed. One approved method is to monitor the battery voltage using an undervoltage relay (function 27CC). Failure of the batteries must be reported to UTAPP via an alarm signal.

When an alternating-current power supply is used to protect the Hydro-Québec system, the static uninterruptible power supply must be continuously monitored. One approved method is to install an internal monitoring module on the static uninterruptible power supply with a dry contact to signal device failure. Failure of the static uninterruptible power supply must be reported to UTAPP via an alarm signal.

9.3.5 Loss of power

Loss of relay power must be dealt with in the trip conditions for the EGF main circuit breaker as follows:

- When using a single multifunction relay for a protection function required by Hydro-Québec, loss of power to the relay must immediately trip the EGF main circuit breaker.
- When using two independent relays for the same protection function required by Hydro-Québec, loss of power to one of the relays can trigger an alarm without causing the EGF main circuit breaker to trip. However, loss of power to both independent relays must immediately trip the EGF main circuit breaker.

Loss of power to the UTAPP or its accessories must trigger an alarm in a protective relay or in the EGF monitoring system.

Loss of power to one or more circuits used to protect the Hydro-Québec system must cause the main circuit breaker of the EGF to trip without delay.

One approved method is to monitor each of the circuits used to protect the Hydro-Québec system with the digital input of a multifunction relay connected to the end of each circuit. The digital input is activated under normal conditions and deactivated when circuit continuity is broken.

For EGFs with a capacity of less than 250 kW, other methods or systems may be approved by Hydro-Québec if it can be demonstrated that the protection system malfunction will trip the EGF main circuit breaker without delay.

9.4 Conditioning of main circuit breaker closing

To ensure the safety of Hydro-Québec employees and the general public, the EGF, through its protection systems or other mechanisms, must not be able to supply the distribution system when it is de-energized.

If relays are used to prevent accidental closing of the EGF main circuit breaker when the distribution system is de-energized, the main circuit breaker closing permissive (section 9.1.6) must be inserted in series into the circuit breaker closing circuit.

Other methods or systems may be approved by Hydro-Québec provided that the intent is met and that it has been demonstrated to Hydro-Québec that these methods or systems are suitable for such use.

Any mechanism for manually closing the EGF main circuit breaker must be permanently disabled or locked out. See sections 5.19 and 5.20 for the requirements respecting lockout and the display of safety notices when locking out the manual closure mechanism on the EGF main breaker.

9.5 EGF main circuit breaker trip control interlock

Activation of the trip signal of the EGF main circuit breaker by a protection function must result in the trip signal being locked in active state by a protection locking function (function 86). The trip signal must remain locked for a minimum of five (5) minutes using a timer (function 62).

When a multifunction relay is used, the action of resetting the locking function must be performed by an external command to the relay. It is forbidden to integrate automatic reset logic for the locking function into the multifunction relay (function 86).

Resetting the locking function can be done using a local command on the EGF or a remote command.[46]

9.6 EGF main breaker trip circuit wiring

Hydro-Québec recommends that the EGF main circuit breaker trip be built according to a fail-safe philosophy. This means that the circuit breaker is designed in such as way that the loss of an electrical circuit, the loss of a component, or the loss of power to the control circuit triggers an inherently safe action by the protection system, namely the immediate opening of the EGF main circuit breaker.

To this end, Hydro-Québec recommends the use of undervoltage relays (UVR) for circuit breaker trip control. Such a design protects against both wiring failure and a loss of power to the circuit breaker's trip coil control circuit.

9.7 Instrument transformers for protection

Instrument transformers used for protection must meet the following requirements:

- They cannot have uses other than the protection of the Hydro-Québec system if equipped with a single secondary winding.
- They must be installed as close as possible to the EGF main circuit breaker on the Hydro-Québec system side.
- One voltage transformer per phase is required. Voltage transformers must have a phase-to-neutral connection. The use of secondary dual winding voltage transformers is acceptable provided the protection function is not affected. In this case, the circuits used to protect the Hydro-Québec system, as well as the circuits dedicated to another use, must all be protected against overcurrent by independent fuses. They cannot be used to supply loads.

[46] In the event that the locking function is reset with an automatic or remote command, in the event of a short circuit in the EGF between the generating units and the EGF main circuit breaker, the EGF main circuit breaker could be closed remotely while there is still a short circuit in the EGF's electrical installation. It is the responsibility of the power producer or self-generator to ensure the integrity of their facility prior to performing switching operations. Hydro-Québec cannot be held responsible for the consequences of switching operations at the EGF, including the closing of the main breaker.

- One current transformer per phase is required. A fourth current transformer can be used to measure neutral current to detect ground faults.
- They are of a suitable class for the application.[47]
- Instrument transformers used to measure current transmitted to a 50/51 and 50N/51N protective function must be of protective class.
- Instrument transformers used to measure voltage and current transmitted to a 32 protective function must be of a metering class.
- Instrument transformers used to measure voltage transmitted to a 27, 59, or 81 protective function must be of metering class.

The installation and characteristics of instrument transformers must be approved by Hydro-Québec.

9.8 Protection coordination and settings

9.8.1 Rules of protection

The protection rules mentioned below serve to properly select and adjust the protection systems used to protect the Hydro-Québec system. They apply to all facilities connected to the Hydro-Québec distribution system. The rules are as follows.

- During phase or ground faults on the distribution system (including the distribution substation busbar), tripping of the EGF main circuit breaker trip must be triggered by its primary protection during the generator's transient state, if possible. For asynchronous generators and IBRs with a capacity of less than 250 kW, it is acceptable, in the case of short circuits, that tripping of the EGF main circuit breaker be initiated by backup protection.
- During phase or ground shorts on the distribution system (including the distribution substation MV busbar), it is acceptable that the primary protection cause the EGF main circuit breaker to open even if undervoltage ride-through times (section 6.4.1) have not yet run out.
- The EGF protection systems must be capable of detecting all short-circuits that Hydro-Québec protections can detect, including resistive phase-to-ground faults with 13.3 ohm impedance (3Rf = 40 ohms) in the overhead system.
- EGF protection systems must be capable of preventing the melting of T-type expulsion fuses and Bay-O-Net fuses installed in the Hydro-Québec MV/LV pad-mounted transformer during a connection based on Standard E.21-11, especially to avoid phase-loss situations.
- The EGF's contribution to faults on lines adjacent to the tie line must not cause the Hydro-Québec circuit breakers on the tie line to trip.
- During faults on the distribution system, the temporary masking of one source's protection systems by another source's fault current contribution doesn't matter, provided that the fault is detected by one of the sources and isolated by the protection systems.
- Degradation of breaker-fuse coordination due to connecting the EGF to the distribution line must be minimized.

[47] Refer to IEEE C37.110 *Guide for the Application of Current Transformers Used for Protective Relaying Purposes* and IEC 61869-1 *Instrument transformers - Part 1: General requirements* and IEC 61869-3 *Instrument transformers - Part 3: Additional requirements for inductive voltage transformers*.

- Any situation that could lead to involuntary EGF islanding on a portion of the distribution system load must cause the EGF main breaker to trip in 2 seconds or less.
- Normal load imbalance on the distribution system must not cause the EGF main circuit breaker to trip. The EGF must therefore be immune to the voltage imbalance normally present on the Hydro-Québec system (sections 6.5 and 6.6).

The order in which tripping occurs between the Hydro-Québec circuit breakers on the tie line and the EGF main breaker is of no importance.

9.8.2 Coordination of generating unit protections

The following rules of protection ensure proper coordination between the generating unit protection systems[48] and the main circuit breaker of the EGF:

- During short-circuits on the distribution system, phase losses, overvoltages, undervoltages, over-frequencies and under-frequencies, the EGF main circuit breaker must open before generating unit protections are activated. This requirement is all the more important if the facility has a UTAPP in order to ensure that the main circuit breaker is locked by the EGF (section 10.5).
- Generating unit protections must not be triggered during transient events on the Hydro-Québec system against which the EGF is supposed to be immunized (sections 6.4 to 6.8).

9.8.3 Voltage protection settings

Voltage protection must:

- provide effective protection against islanding on the distribution line or substation busbar load
- offer effective backup protection against faults occurring on the distribution system
- be capable of interrupting generation within a reasonable time in the event of a voltage regulation problem at the generating station
- be sufficiently selective to prevent tripping during events on the bulk power system

The settings below meet these requirements.

Table 12 and Table 13 show the voltage protection settings. These are based on the values in Tables 8 and 9 in section 12.2 of *Exigences techniques de raccordement de centrales au réseau de transport d'Hydro-Québec* [technical requirements for the interconnection of generating stations to the Hydro-Québec transmission system] as well as on section 6.4 of Standard IEEE 1547-2018.

[48] Generating unit protections can be implemented using circuit breakers and unit protection relays, by adjusting the protection settings integrated into the inverter in the case of IBRs, or by any other method that ensures generating unit selectivity.

Appendix G: presents overlay graphs showing undervoltage and overvoltage ride-through requirements and protection thresholds.

Table 12: Voltage protection settings

Voltage (% of nominal voltage)[1]	Trip threshold[2]
125%	0.16 seconds
120%	2 seconds
110%	13 seconds
88%	21 seconds
50%	2 seconds

1. Fundamental frequency RMS voltage for a single-phase EGF. Phase-to-neutral and phase-to-phase RMS voltage for each of the phases of a three-phase EGF. If one of the phases reaches the trip threshold, the EGF must trip all three phases.
2. The maximum length of time the EGF can remain in service (must trip) following a disturbance.

Table 13: IBR voltage protection settings

Voltage (% of nominal voltage) [1]	Trip threshold[2]
120%	0.16 second[3]
110%	13 seconds
88%	21 seconds
50%	2 seconds

1. Fundamental frequency RMS voltage for a single-phase EGF. Phase-to-neutral and phase-to-phase RMS voltage for each of the phases of a three-phase EGF. If one of the phases reaches the trip threshold, the EGF must trip all three phases.
2. The maximum length of time the EGF can remain in service (must trip) following a disturbance.
3. UL1741-SB– certified IBRs with a capacity of less than 250 kW must block or trip within 0.017 seconds at voltages greater than 138% of the nominal voltage (section 7.3).

9.8.4 Frequency protection settings

Frequency protection must:

- ensure some protection against islanding on the distribution line or substation busbar load
- be fast enough to be coordinated with distribution and transmission line reclosing times
- be set to overfrequency trip thresholds near 60 Hz, and be fast enough to avoid the overvoltage problems associated with asynchronous generators
- be selective enough to avoid most trips caused by events on the bulk power system

The settings below allow these requirements to be met.

Table 14 and Table 15 show the settings for frequency protection. These are based on the values in Table 10 of section 12.2.3 of *Exigences techniques de raccordement de centrales au réseau de transport d'Hydro-Québec* [technical requirements for the interconnection of generating stations to the Hydro-Québec transmission system].

When frequency variations occur, the trip thresholds in Table 14 and Table 15 take precedence over the requirements for frequency variation ride-through (section 6.7.2).

Appendix G: presents overlay graphs showing ride-through requirements and protection thresholds.

Table 14: Frequency protection settings

Frequency (Hz)	Trip threshold[2]
63.5	0.35 second
63.0 [1]	5 seconds
61.5	180 seconds
58.5	180 seconds
57.0	2 seconds
55.5	0.35 second

1. Instantaneous tripping is allowed starting at 61.7 Hz in 0.35 seconds for the following EGFs:
   (a) EGFs with synchronous generators having a total capacity less than or equal to 250 kW
   (b) Thermal and gas turbine EGFs
   (c) EGF equipped with asynchronous generators.
2. The maximum length of time the EGF can remain in service (must trip) following a disturbance.

Table 15: IBR frequency protection settings

Frequency (Hz)	Trip threshold[1]
61.7	0.35 second
61.5	180 seconds
58.5	180 seconds
55.5	0.35 second

1. Maximum period during which the IBR may remain in service (must trip) following a disturbance.

9.8.5 Minimum load protection settings

The setting for the directional power protection ($P_{Function\,32}$) must be adjusted to a value equal to or greater than the minimum power required to flow at the Point of Connection towards the customer's facility to ensure the minimum required load-to-generation ratio is maintained. Equation 5 details how to make this calculation.

$$P_{Function\,32} \geq (P_{EGF\,name} Load/production\,ratio) - P_{EGF\,name}$$

$P_{Function\,32}$: Directional Power Shield Adjustment (kW)
$P_{EGF\,name}$: Rated capacity of the EGF (kW)
$Load/production\,ratio$: Minimum load/production ratio based on EGF group type

Equation 5: Calculation of the protection setting to ensure a minimum load to mitigate the risk of prolonged involuntary island

The Directional Power Protection Working Time shall be adjusted to one (1) second.[49]

9.8.6 Protection settings to limit injection of power

Directional power protection (function 32) must be set between 0 and 200 kW to the Hydro-Québec system with a one (1) second start time.[49]

9.8.7 Protection settings to limit contribution to overvoltage

The protection to limit the overvoltage contribution shall be set to a voltage of 138% of the nominal phase-to-neutral and phase-to-phase voltage value with a startup time of one (1) cycle at the basic frequency of the system, approximately seventeen (17) milliseconds.

9.8.8 EGF Main Breaker Closing Permissive Settings

Table 16 shows the voltage and frequency threshold settings used for the closing permissives of the EGF main circuit breaker".

Table 16: EGF Main Breaker Closing Permissive Settings

Position	Startup threshold	Time delay
Undervoltage (function 27)	LV connection: 88%[1] MV connection: 94%[1]	300 seconds
Overvoltage (function 59)	106%[1]	300 seconds
Under Frequency (81U Function)	59.4 Hz	Instantaneous
Frequency (81O function)	60.6 Hz	Instantaneous

1. % of nominal voltage. Fundamental frequency RMS voltage for a single-phase EGF. Phase-to-neutral RMS voltage for each of the phases of a three-phase EGF.

[49] The directional power protection (function 32) shall be coordinated with the undervoltage and overvoltage ride-through requirements presented in section 6.4. For this reason, the Directional Power Protection Start Time is set to one (1) second, which is the minimum amount of time to pass through voltage less than 50% of the nominal voltage.

If a directional power element is used in the permissives (function 32), the threshold must be adjusted to a value between[50]:

- the value of the minimum power required to flow at the Point of Connection towards the customer's facility to ensure the minimum required load-to-generation ratio when the EGF operates at its rated capacity ($P_{Function\ 32}$)[see section 9.8.5]
- the value of the customer's load required to flow at the Point of Connection to the customer's facility before EGF startup to ensure the minimum load-to-generation ratio when the EGF operates at its rated capacity (see section 9.8.5)

The selected value will need to be approved by Hydro-Québec.

9.8.9 Breaker failure protection settings

The maximum opening delay setting for the main circuit breaker shall be equal to or less than two (2) times the average opening time for the breaker, increased by a safety margin of 20%. For example, for a circuit breaker with an opening time of five (5) cycles, the maximum opening time for fault detection will be set to twelve (12) cycles or less.

10 Remote monitoring and remote control requirements

The EGF owner must provide a telecommunication link, at its own expense, to enable Hydro-Québec's distributed energy resource management system (DERMS) to communicate with the EGF.

The EGF owner must also configure its facility to ensure continuous connectivity between the EGF and Hydro-Québec's DERMS. TCP/IP telecommunications system connections, under the responsibility of the EGF owner, must be wired. A wireless connection between EGF generating units and Internet connectivity equipment is not permitted.

Hydro-Québec may remotely change the EGF's IBR settings with or without notice.

10.1 Communication protocol

The EGF must be compliant with Standard IEEE 2030.5 / Sunspec Common Smart Inverter Profile (CSIP) version 2.1 or higher with TCP/IP connectivity to meet the visibility, predictability and controllability requirements of the Hydro-Québec distribution system. This standard defines the requirements stemming from the protocols needed to collect and report the EGF's real-time electricity consumption and generation data.

Connectivity and compliance with Standard IEEE 2030.5 can be achieved in three different ways:[51]

- The EGF inverter or generating unit may be IEEE 2030.5 compliant and be equipped, for example, with an RJ45 network communication port that allows the inverter or unit to be connected to an Internet connectivity device such as a router. In this case, IEEE 2030.5 compliance is embedded in the inverter or group.
- The inverter or EGF group can be connected, using another protocol, to a communication gateway that provides connectivity and compliance with the Standard IEEE 2030.5. This gateway will then be equipped with an RJ45 network communication port that allows it to be connected to an Internet

[50] For example, for an EGF using IBRs with a capacity of 1 MW, the directional power element setpoint in the permissive protections (function 32) shall be set between 100 kW (1.0 x 1.1 – 1.0 = 0.1 MW) and 1.1 MW (1.0 + 0.1 = 1.1 MW).
[51] Hydro-Québec recommends that IEEE 2030.5 compliance be embedded in the inverter, the generating units or a locally installed communication gateway. The use of cloud-based software to achieve IEEE 2030.5 compliance could lead to connectivity issues, increase EGF response time, and engender long-term compatibility issues in the event of a vendor shutdown. If cloud-based software is used to achieve IEEE 2030.5 compliance, this service must be at no cost to Hydro-Québec.

connectivity device such as a router. This is the case, for example, with several generator models, which must be connected to a gateway using a serial link via the Modbus protocol. In this case, IEEE 2030.5 compliance is embedded in the gateway.

- For example, the inverter or EGF group may be equipped with an RJ45 network communication that allows the inverter or group to be connected to an Internet connectivity device such as a router, without being IEEE 2030.5 compliant itself. The EGF's inverter or generating unit will then communicate with a cloud-based service via a closed protocol. In this case, IEEE 2030.5 compliance is localized to the cloud.

10.2 Configuring inverter settings for an IBR

In the case of an EGF using an IBR but with protective relays, Hydro-Québec may manually or dynamically change the voltage protection, frequency protection, voltage regulation and frequency regulation settings of the EGF inverter at any time without notice to ensure the safety of Hydro-Québec employees and the public, as well as voltage quality and electrical service continuity.

10.3 Limit generation command

Hydro-Québec may manually or remotely limit generation at an EGF at any time and without notice in order to correct system constraints or when work is being carried out.

10.4 Generation trip command

Hydro-Québec may, at any time and without prior notice, manually or remotely trip the EGF's generation and disconnect it from the power system in the event of an emergency, to address system constraints, or during maintenance work.

10.5 UTAPP installation

If installation of a UTAPP is required by Hydro-Québec, the EGF owner will refer to standards E.12-12 and F.22-05 for UTAPP installation and measurement requirements.

10.6 Metering of electricity

The metering equipment provided by Hydro-Québec must be a communicating meter[52] so that Hydro-Québec's DERMS can maintain constant connectivity with the meter.

11 Islanded generation

Hydro-Québec does not allow islanded generation on loads other than the customer's for facilities covered by this standard (see Section 12).

12 Backup power supply

The EGF owner may use their EGF as a backup power supply to power their own loads during a power outage. To do so, their facility must meet the following conditions:

1. It must comply with section 15.2.5 *Protection for backup generator* of Hydro-Québec's *Conditions of Service*. The EGF must be designed in such a way that if it is shut down, critical loads can be supplied

[52] See *Chapter 3 – Metering of Electricity* of Hydro-Québec's *Conditions of Service*.

by the Hydro-Québec system. Therefore, a switching device with a mechanical interlock system is required if the shut down of the inverter prevents the supply of critical loads by Hydro-Québec's system. This switching device must fall within one of the four following categories (see Appendix I):

a. Device equipped with a mechanical interlock system[53]

b. Double throw safety switch certified under CSA C22.2 No. 4 or UL 98

c. Manual transfer switch certified under CSA C22.2 No. 178.1 or UL 1008

d. Automatic transfer switch certified under CSA C22.2 No. 178.1 or UL 1008

2. If a manual or automatic transfer switch is used, the backup generation source can only be connected to the "emergency" terminal of the transfer switch. Connecting a source of electricity generation to the "load" terminal of the transfer switch is prohibited.[54]

3. If backup power has an operating mode requiring reactance grounding, a protection system must be in place allowing for confirmation of termination of emergency mode and removal or insertion of the reactance grounding, as required, prior to resynchronization with the Hydro-Québec distribution system;

4. If the EGF is equipped with IBR:

   a. If the EGF does not have a microgrid interconnect device (MID), the inverter must be equipped with two distinct connection terminals, one to connect to the distribution system and the other to connect to the customer's critical loads. Each of the connection terminals must have a connection point for the neutral wire.

   b. The inverter's backup power must be supplied exclusively from a direct-current source.

   c. If a backup generator is installed, Hydro-Québec requires that it have a switching device with a mechanical or certified interlock. The inverter must not be used as a transfer switch.[55] Refer to the appendices in Standard E.12-07 for diagrams of standard backup generator connections for EGFs using IBRs.

   In addition, for EGFs equipped with a microgrid interconnection device, refer to section 10 *Alimentation de secours* [backup power] in E.12-07 for specific requirements.

Revision history

Date YYYY-MM-DD	Amendment	Administrative unit in charge
2004/11/01	Original version	Éric Le Courtois, Eng. (System Orientations)
2009/02/09	Update	Charles-Étienne Côté, Jr. Eng. (Technology Orientations)
2025-11-17	Complete revision. Consolidation of standards E.12-01, E.12-05 and E.12-06.	Philippe Venne, Eng. (Innovation Strategies and Projects – Energy System)

[53] The mechanical interlock system must be installed permanently and in such a way that it cannot be removed or bypassed by the final user without the help of tools.
[54] Connecting a source of electricity generation to the "load" terminal of the transfer switch could lead to an out-of-sync closing of the transfer switch, which would cause overvoltages and damage to the customer's equipment, the source of electricity generation and the Hydro-Québec system.
[55] Multimode inverters are not certified to Standard CSA C22.2 No. 178.1, *Transfer Switch Equipment*. As a result, they cannot be used to connect a backup generator to a customer facility. Failure to comply with this directive may result in damage to the inverter or injury to Hydro-Québec employees. The customer would then be liable for the damage.

References

- Characteristics of the voltage supplied by the Hydro-Québec medium- and low-voltage systems [in French only]
- CSA C22.2 No. 178.1 *Transfer switch equipment*
- CSA C22.10 *Quebec Construction Code – Chapter V – Electricity – Canadian Electrical Code,* Part I and Amendments of Quebec
- CSA C235-R2019 *Preferred voltage levels for AC systems up to 50,000 V*
- CSA IEC 61000-4-27:01 *Electromagnetic Compatibility (EMC) – Part 4-27: Testing and Measurement Techniques - Unbalance, immunity test*
- CSA Z460:20 *Control of Hazardous Energy: Lockout and Other Methods*
- CSA Z462:24 *Workplace Electrical Safety*
- EPRI number 3002020130 *Effective Grounding for Inverter-Connected DER*
- IEC 62786-1 *Distributed energy resources connection with the grid – Part 1: General requirements*
- IEEE C57.105, *Guide for Application of Transformer Connections in Three-Phase Distribution Systems*
- IEEE C57.110, *Recommended Practice for Establishing Liquid-Immersed and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsinusoidal Load Currents*
- IEEE C62.92.1 *Guide for the Application of Neutral Grounding in Electrical Utility Systems--Part I: Introduction*
- IEEE C62.92.2 *Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part II—Synchronous Generator Systems*
- IEEE C62.92.4 *Guide for the Application of Neutral Grounding in Electrical Utility Systems--Part IV: Distribution*
- IEEE C62.92.6 *Guide for Application of Neutral Grounding in Electrical Utility Systems, Part VI--Systems Supplied by Current-Regulated Sources*
- IEEE 1547 *Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*
- IEEE 1547.1 *Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces*
- IEEE 2030.5 *Standard for Smart Energy Profile Application Protocol*
- UL 1741 *Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources*
- UL 1741 Supplement B *Grid support utility-interactive inverters and converters based on IEEE 1547-2018 and IEEE 1547.1-2020*

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Document Tracking and Authentication

Responsibilities

Responsibility for application
All management staff – Integrated and Optimal Energy System Design

Prepared by

First and last name, title and administrative unit of this section's signatories	Signature	Date YYYY-MM-DD
Philippe Venne Engineer - Innovation Projects and Strategies – Energy System		

Verified by

First and last name, title and administrative unit of this section's signatories	Signature	Date YYYY-MM-DD
Dominique Boulé-Racine Engineer - Innovation Projects and Strategies – Energy System		

Administrative approval

First and last name, title and administrative unit of this section's signatories	Signature	Date YYYY-MM-DD
Louis-Simon Gauthier Head - Innovative Solutions and Specialized Services – Inn. Strategies and Projects. – ES and customers		
Michael Fauchon Manager - Applied Innovation Solutions and Sector Expertise		

Title of guideline	Guideline number	Effective date YYYY-MM-DD
Technical requirements for distributed generation interconnection to the Hydro-Québec distribution system	**E.12-01**	**2025-11-17**

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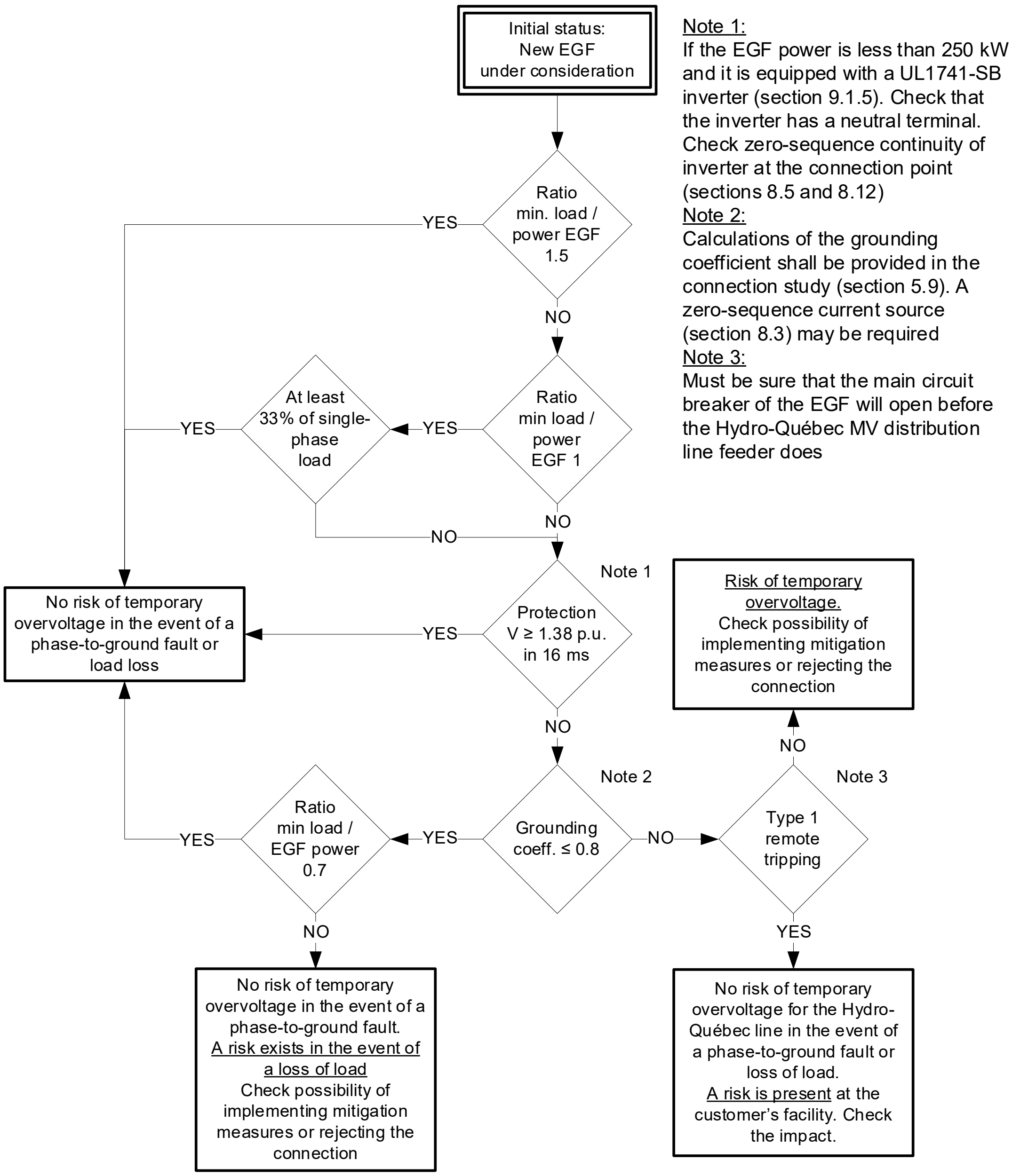
APPENDIX A

Request to connect generation equipment to the Hydro-Québec system



For a connection as a Self-generation customer:
https://www.hydroquebec.com/self-generation/

For a connection as a power producer further to a Hydro-Québec request for proposals or electricity purchase program:
https://www.hydroquebec.com/transenergie/en/connecting-to-hydroquebec-system.html.

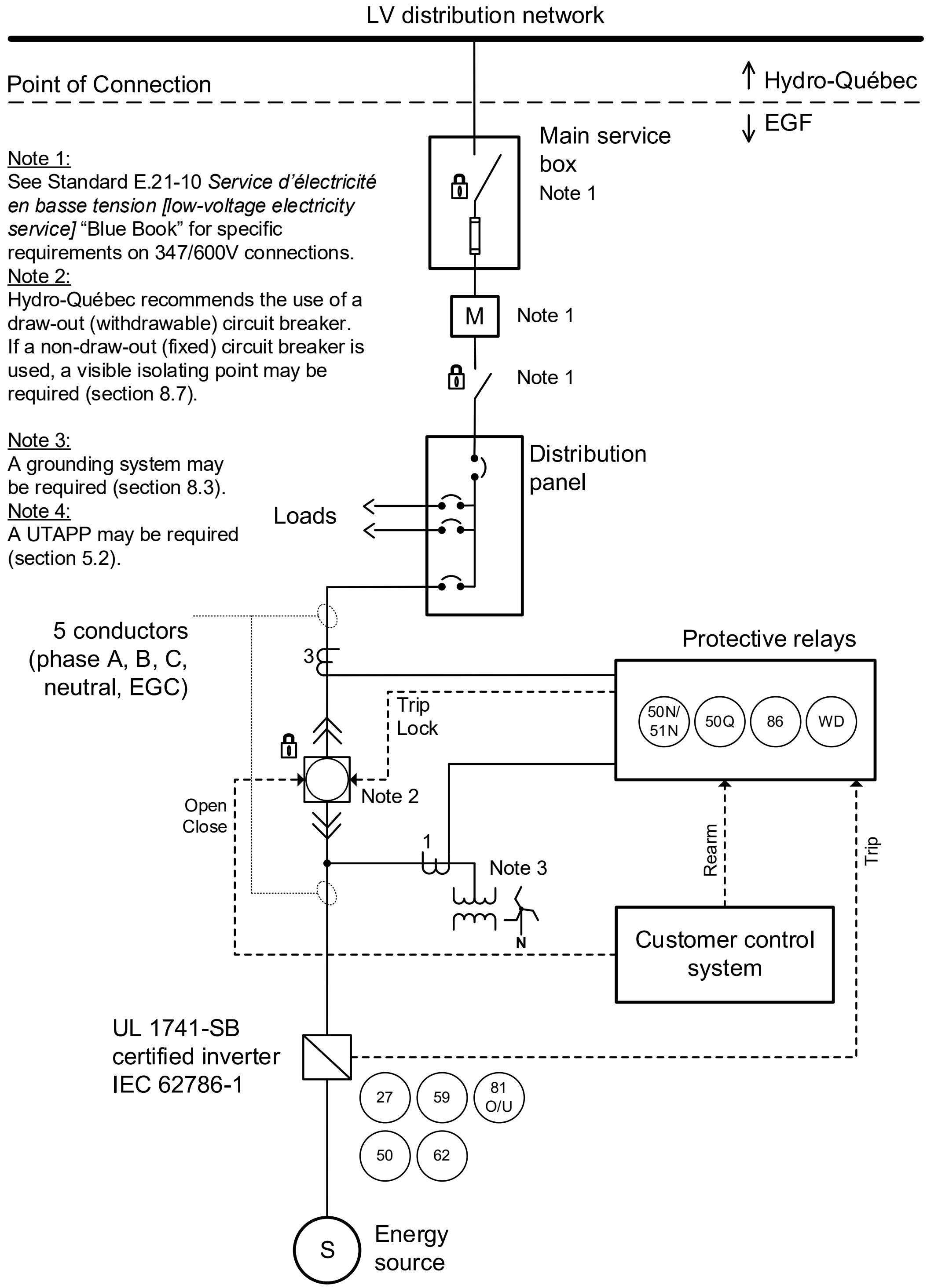
Appendix B

Typical connection and protection diagrams for EGFs

IMPORTANT

The figures shown in Appendix C are for information purposes only. They must not be used as definitive instructions for the design, installation or construction of an EGF. The customer or its authorized representative remains responsible for the implementation and operation of the EGF and the issues or disturbances it might cause.

List of figures



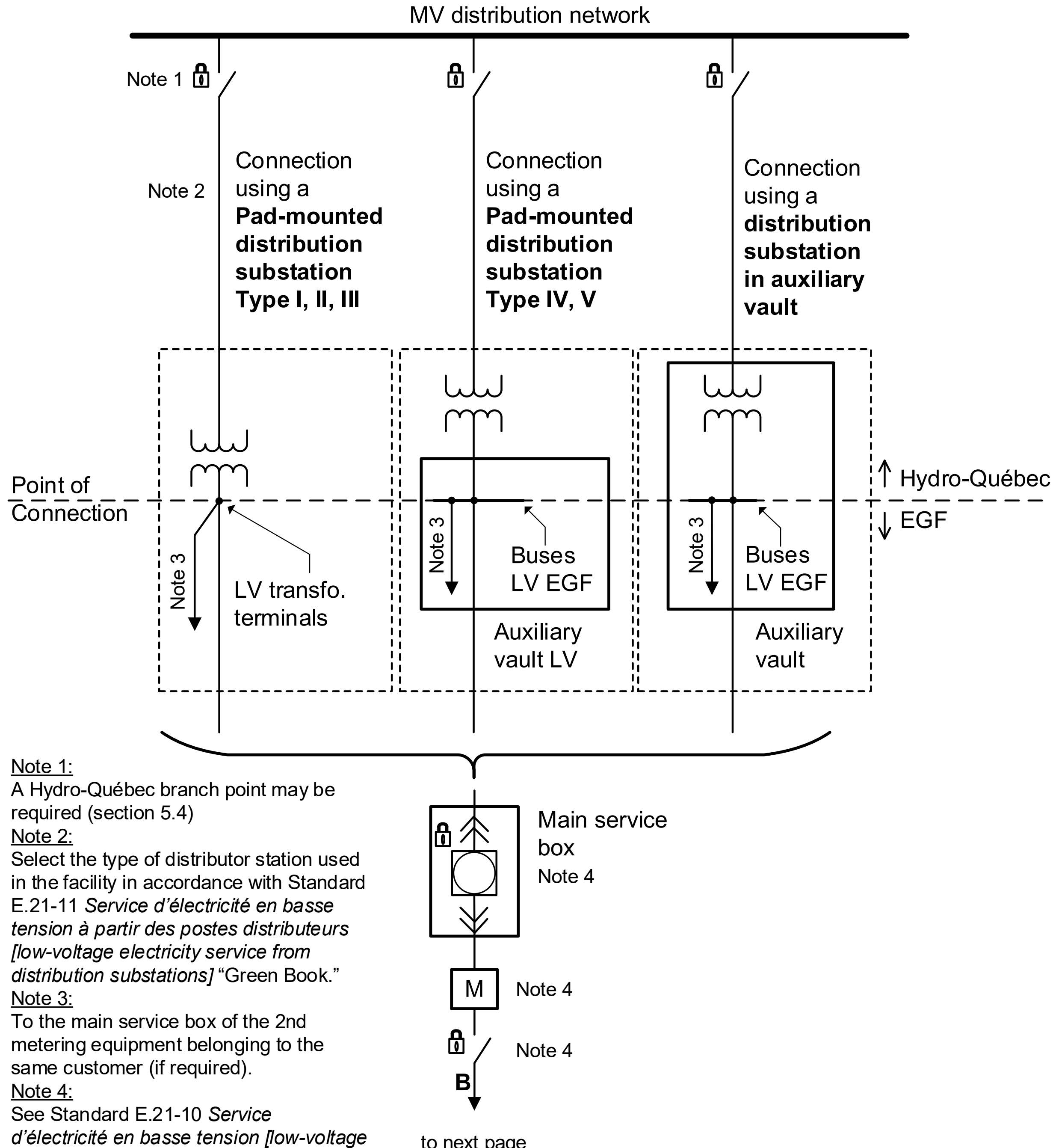
Note 1:
See Standard E.21-10 *Service d'électricité en basse tension [low-voltage electricity service]* "Blue Book" for specific requirements on 347/600V connections.

Note 2:
Hydro-Québec recommends the use of a draw-out (withdrawable) circuit breaker. If a non-draw-out (fixed) circuit breaker is used, a visible isolating point may be required (section 8.7).

Note 3:
A grounding system may be required (section 8.3).

Note 4:
A UTAPP may be required (section 5.2).

Figure 1: LV connection diagram for an EGF with a capacity of 250 kW greater, 600A or less at the Point of Connection, using a certified 347/600V three-phase inverter



Note 1:
A Hydro-Québec branch point may be required (section 5.4)

Note 2:
Select the type of distributor station used in the facility in accordance with Standard E.21-11 *Service d'électricité en basse tension à partir des postes distributeurs [low-voltage electricity service from distribution substations]* "Green Book."

Note 3:
To the main service box of the 2nd metering equipment belonging to the same customer (if required).

Note 4:
See Standard E.21-10 *Service d'électricité en basse tension [low-voltage electricity service]* "Blue Book" for the specific metering requirements.

Figure 2: LV connection diagram for an EGF with a capacity of 250 kW or greater, more than 600A at the Point of Connection, requiring separate EGF metering, using a certified 347/600 V three-phase inverter

Note 4:
Hydro-Québec recommends the use of a draw-out (withdrawable) circuit breaker. If a non-draw-out (fixed) circuit breaker is used, a visible isolating point may be required (section 8.7).
Note 5:
A grounding system may be required (section 8.3).
Note 6:
If a power transformer is required, use a 5-leg transformer with a Y(Neutral)-Y(Grounded) winding (section 8.12).
Note 7:
A UTAPP may be required (section 5.2).

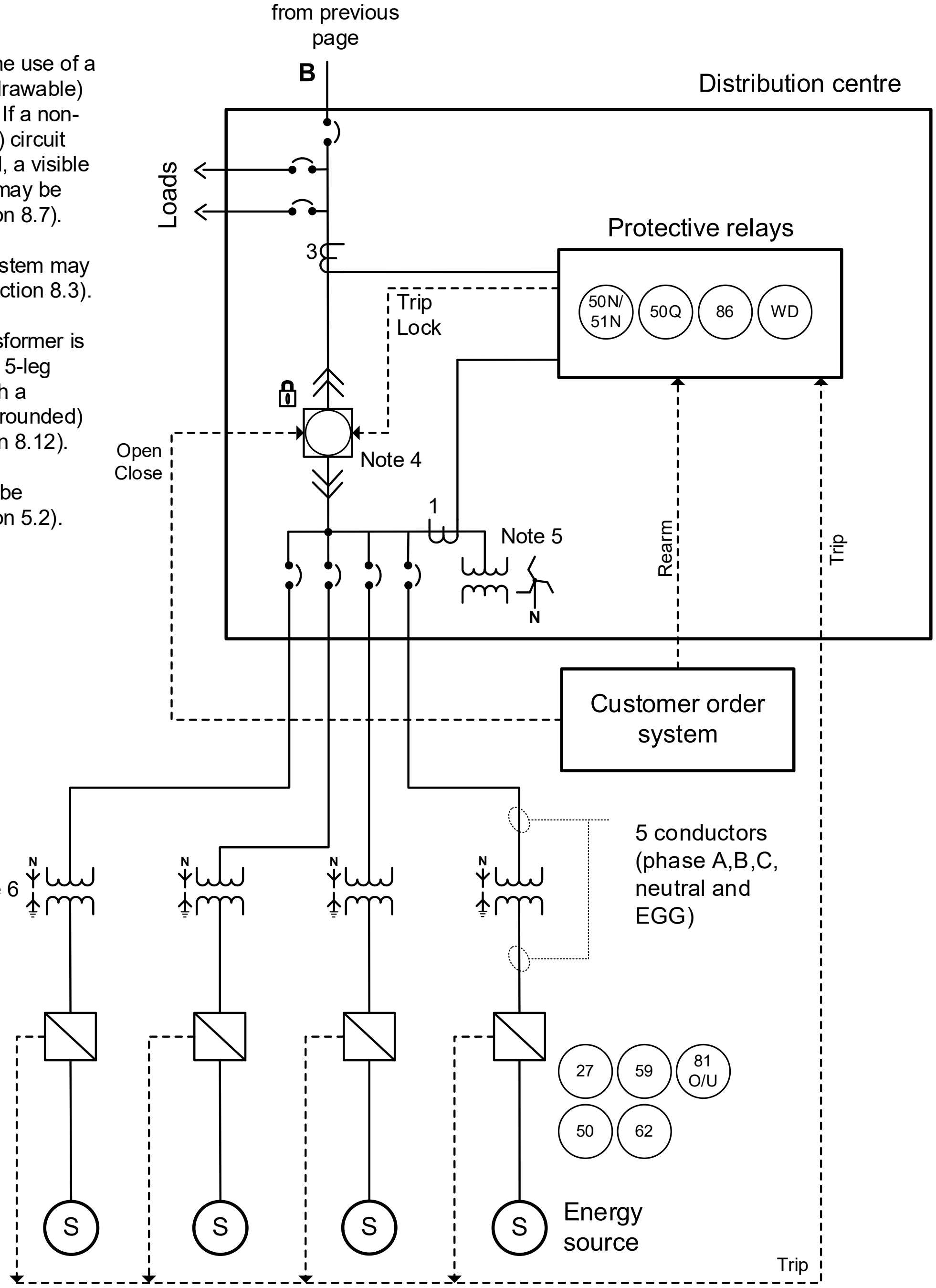


Figure 2 cont'd: LV connection diagram for an EGF with a capacity of 250 kW or greater, more than 600A at the Point of Connection, requiring distinct EGF metering, using a certified 347/600 V three-phase inverter

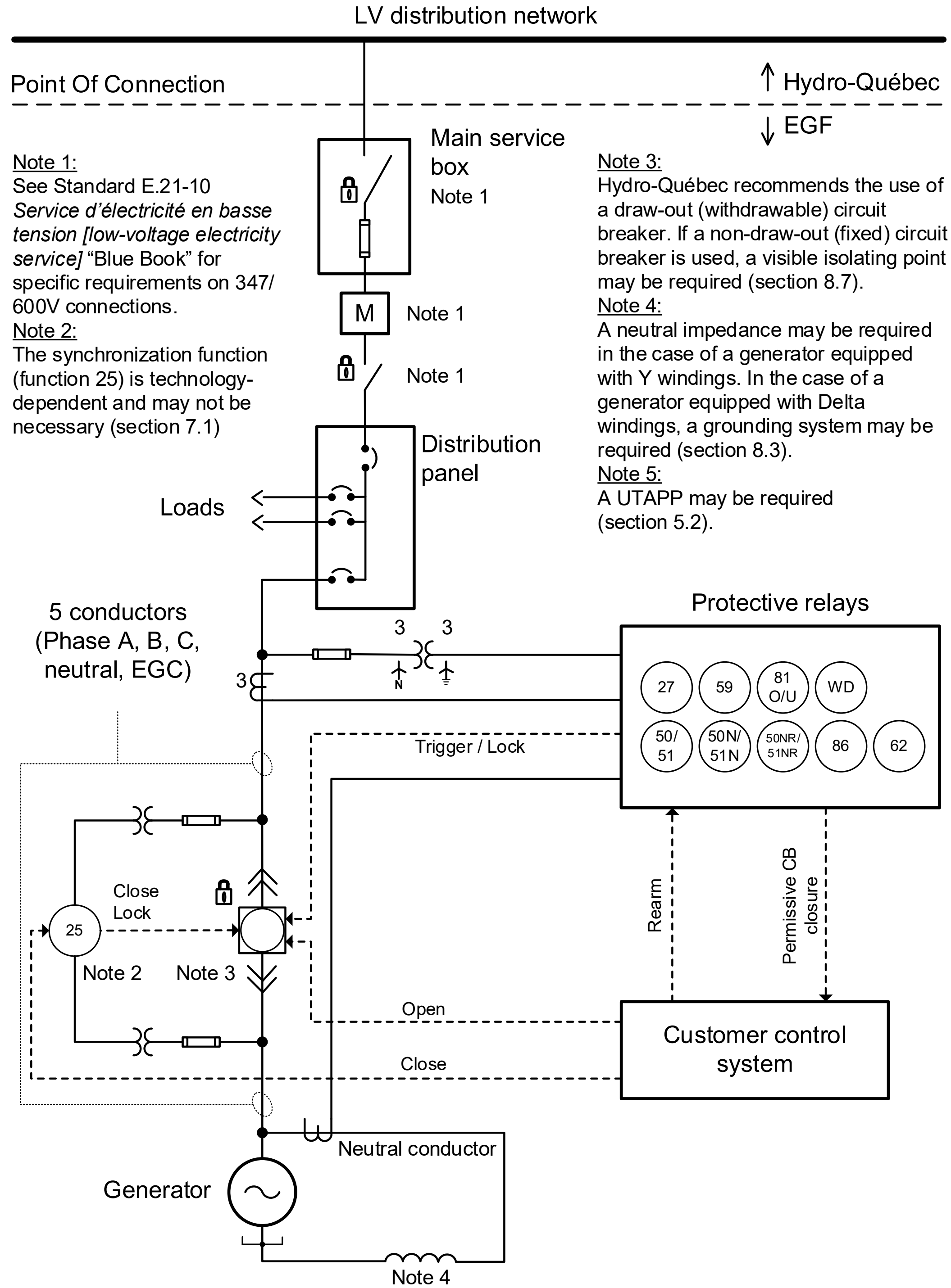


Figure 3: LV connection diagram for an EGF using a 347/600 V three-phase generator

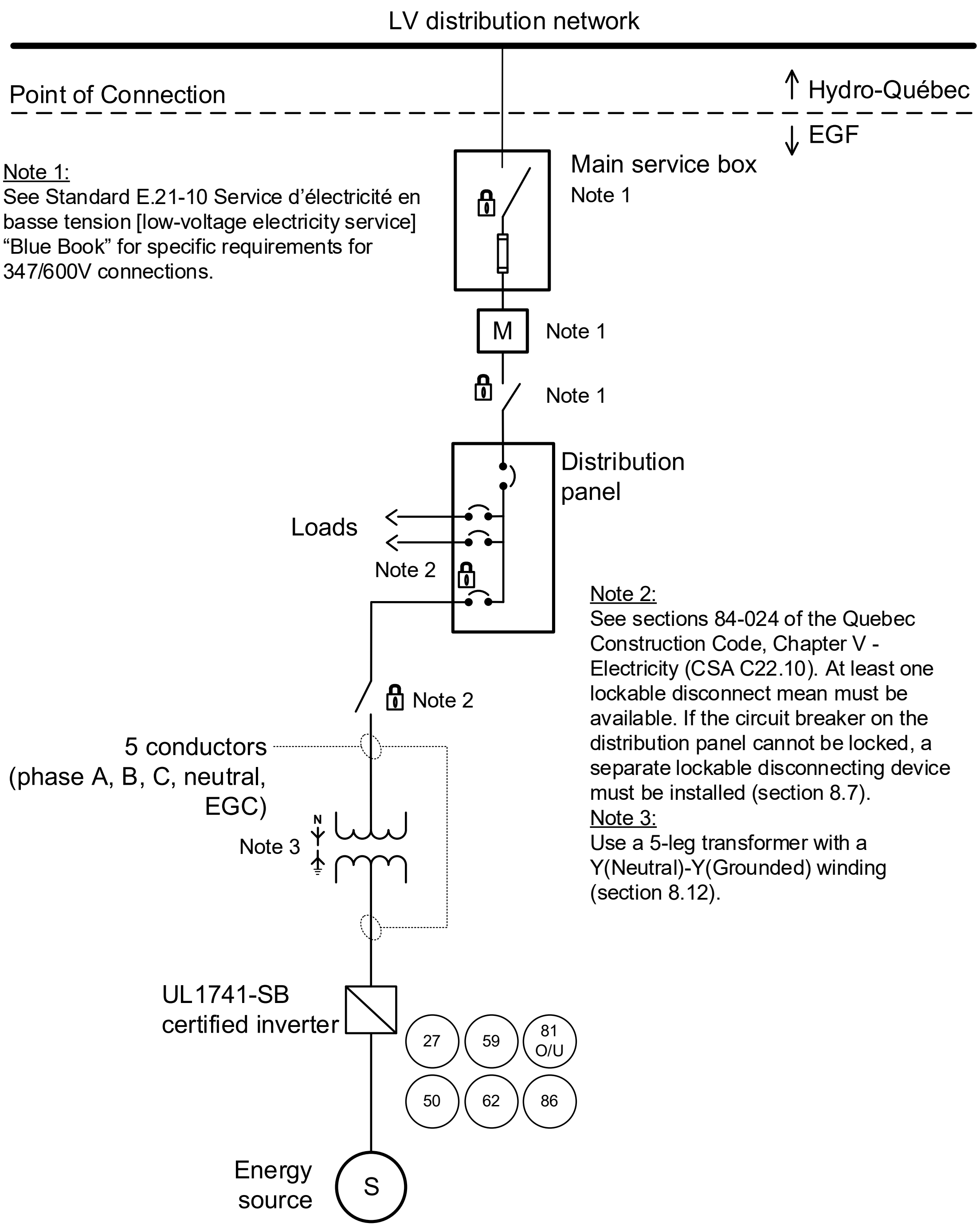


Figure 4: LV connection diagram for an EGF with a capacity of less than 250 kW using a certified inverter with neutral terminal and a Y(Neutral)-Y(Grounded) power transformer

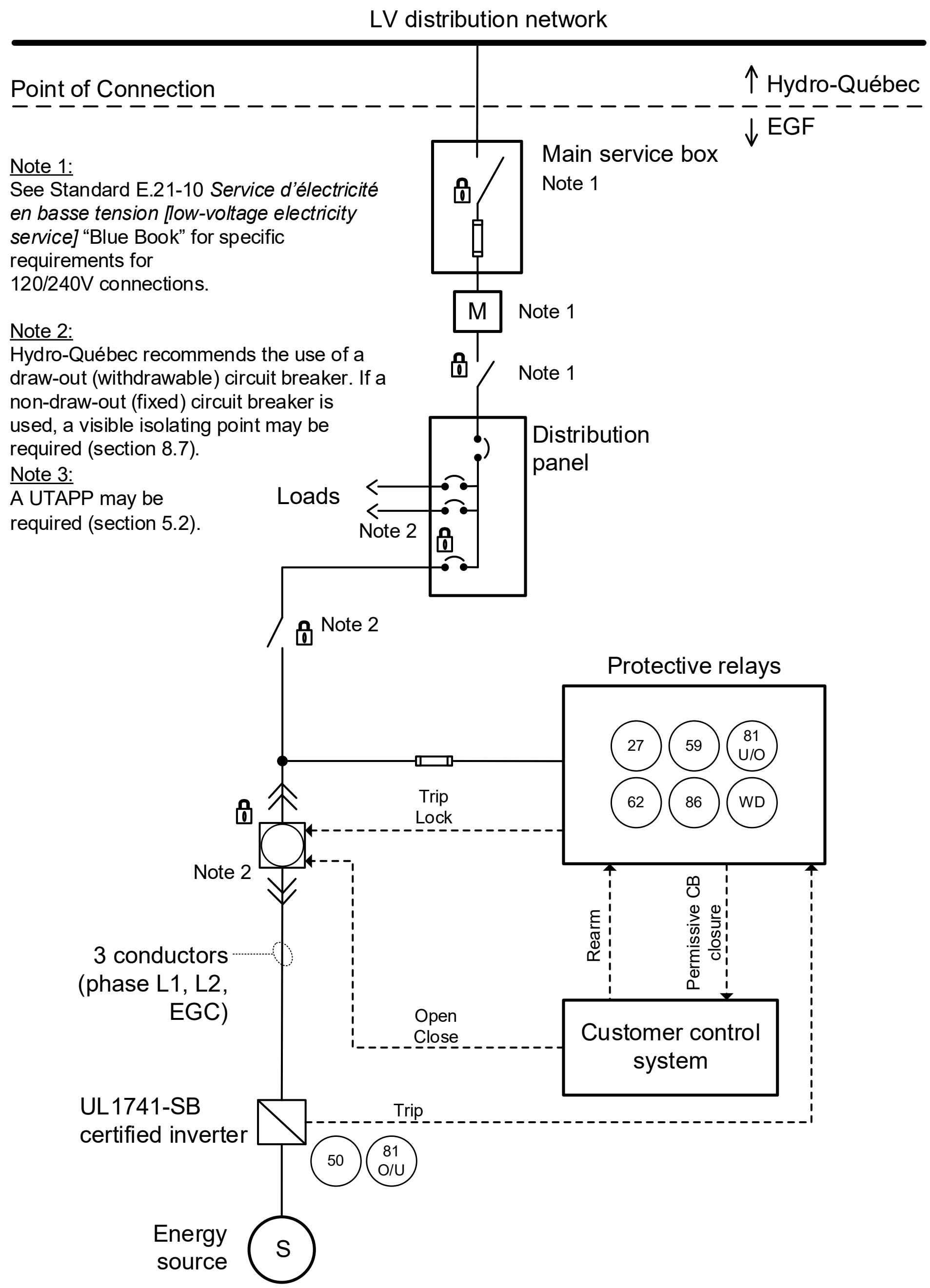


Figure 5: LV connection diagram for an EGF using a certified 240 V inverter, without neutral terminal or power transformer

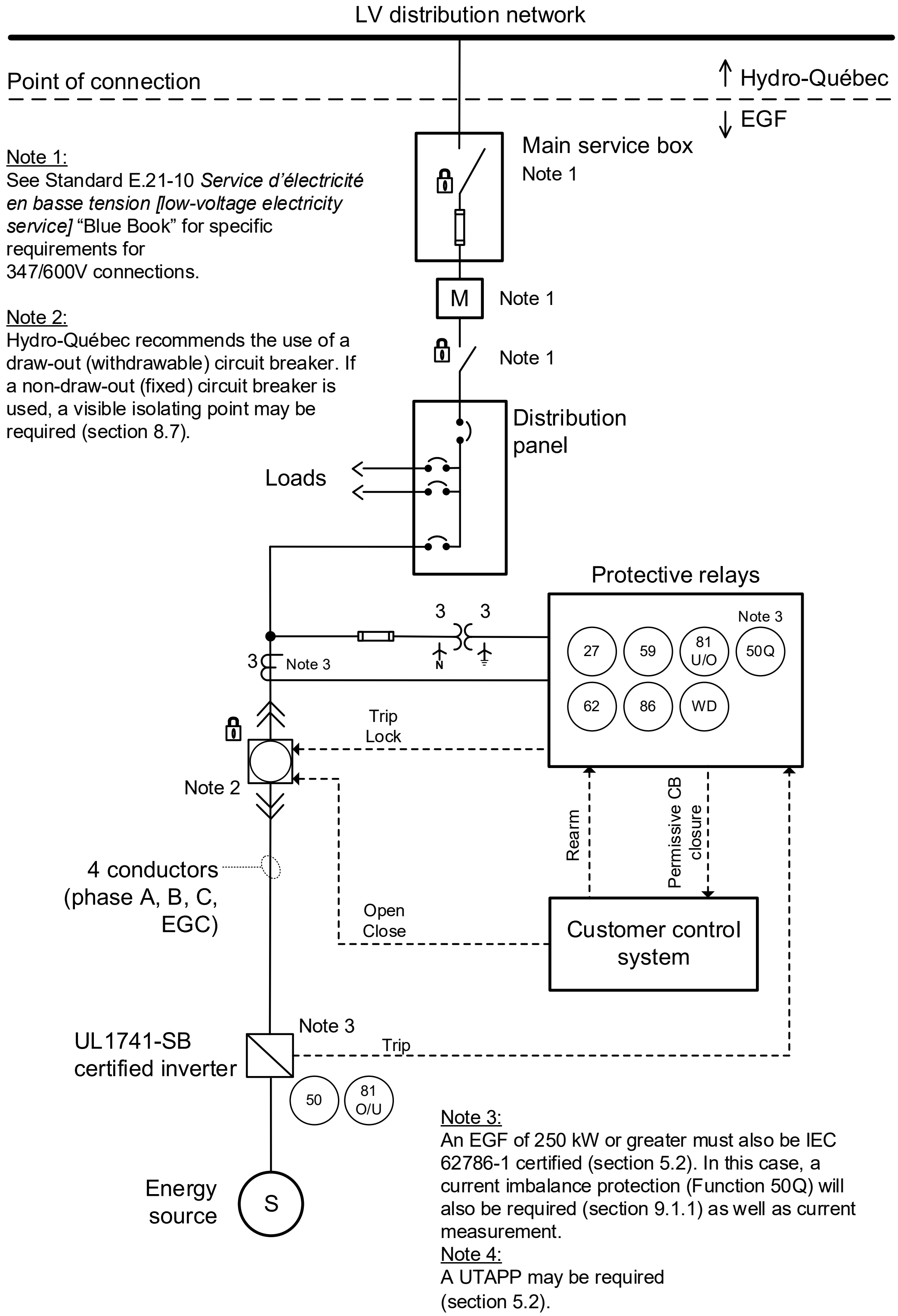


Figure 6: LV connection diagram for an EGF using a certified 600 V inverter, without neutral terminal or power transformer

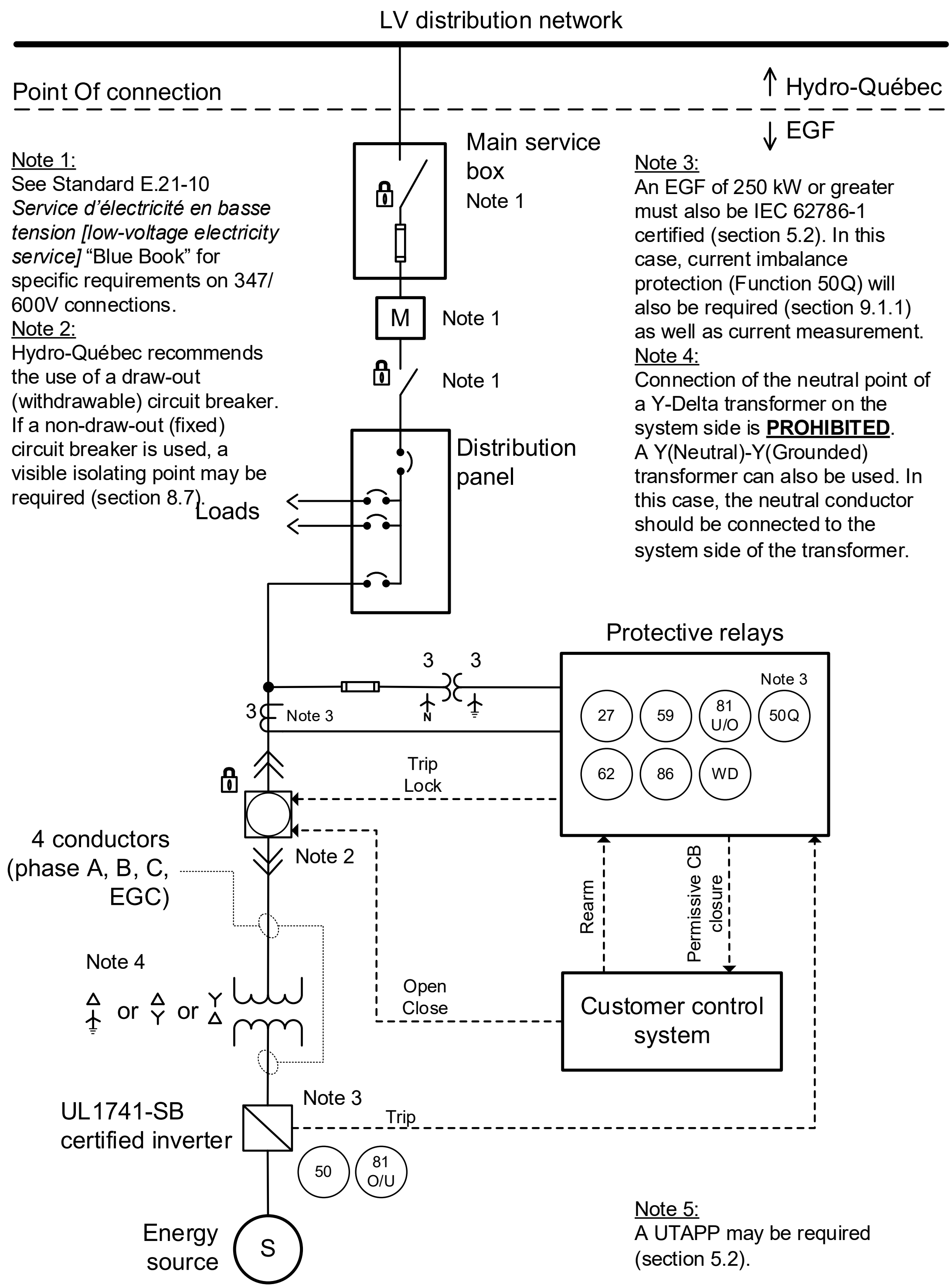


Figure 7: LV connection diagram of and EGF using a certified inverter without neutral terminal and with a Delta-Y(ground), Delta-Y, Y-Delta or Y(neutral)-Y(Grounded) power transformer

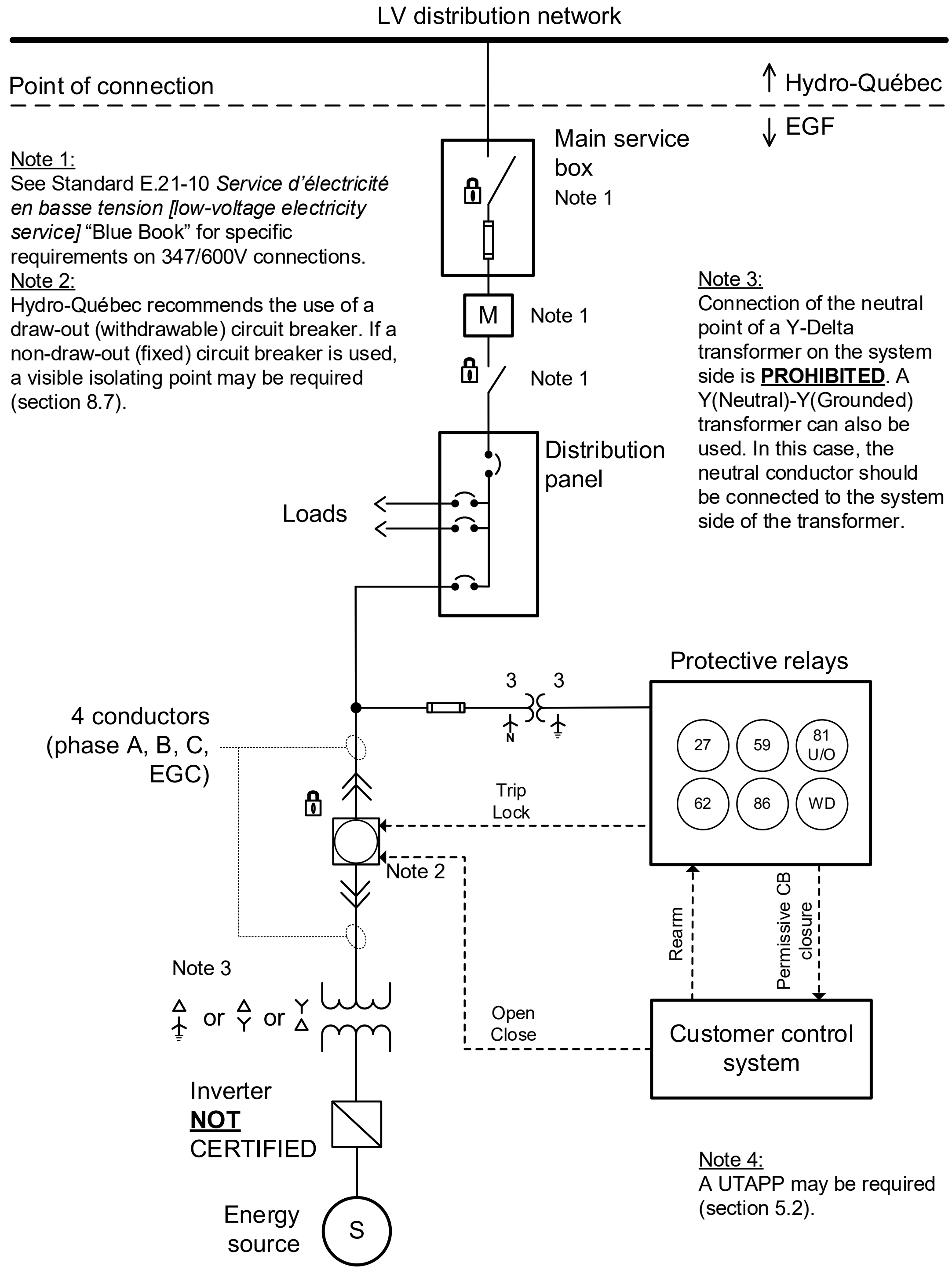


Figure 8: LV connection diagram for an EGF using an uncertified inverter, with or without Delta-Y(Grounded), Delta-Y, Y-Delta or Y(Neutral)-Y(Grounded)

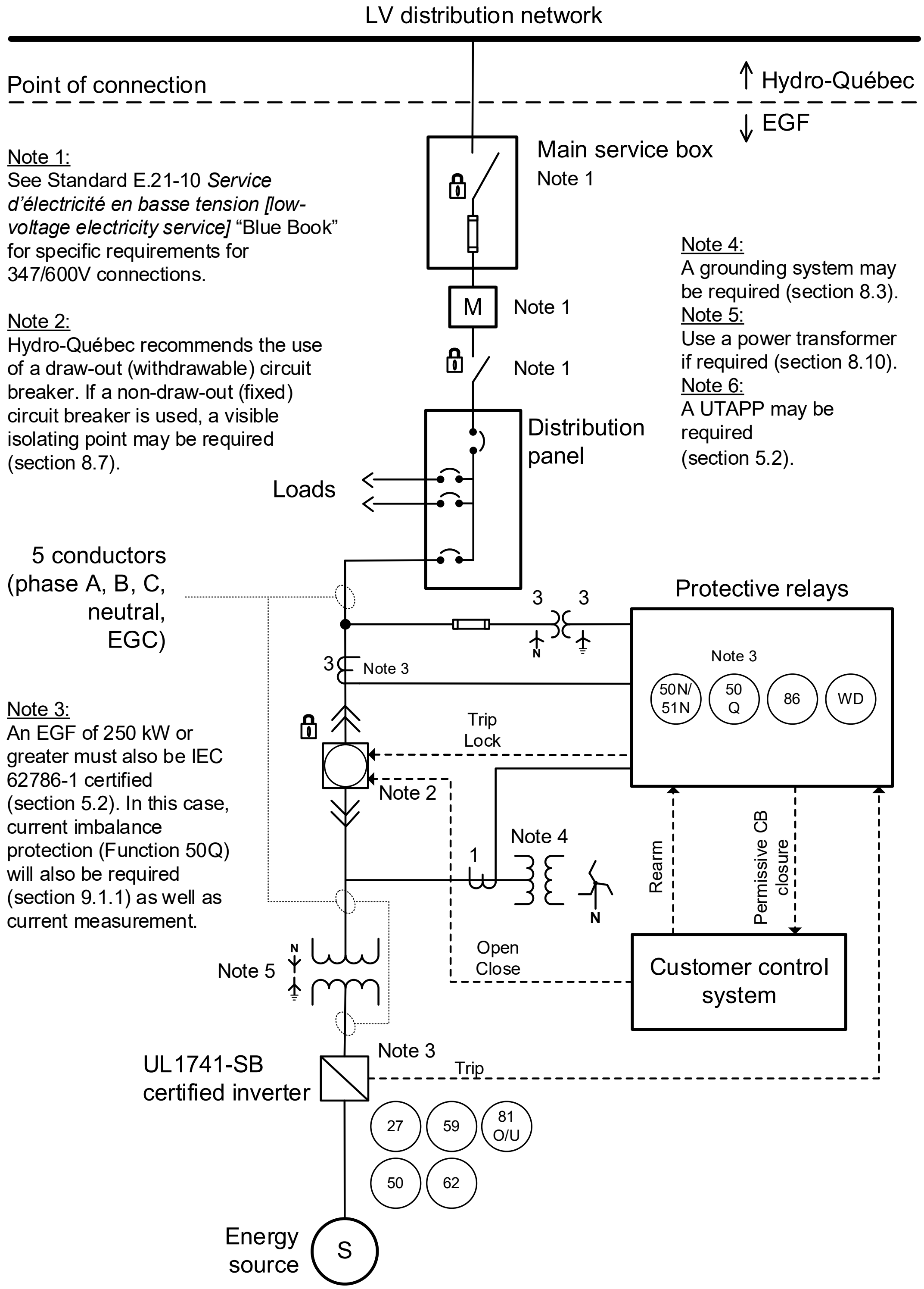


Figure 9: LV connection diagram for an EGF using a certified 347/600 V inverter, with neutral terminal, with or without Y(Neutral)-Y(Grounded) power transformer, with grounding transformer

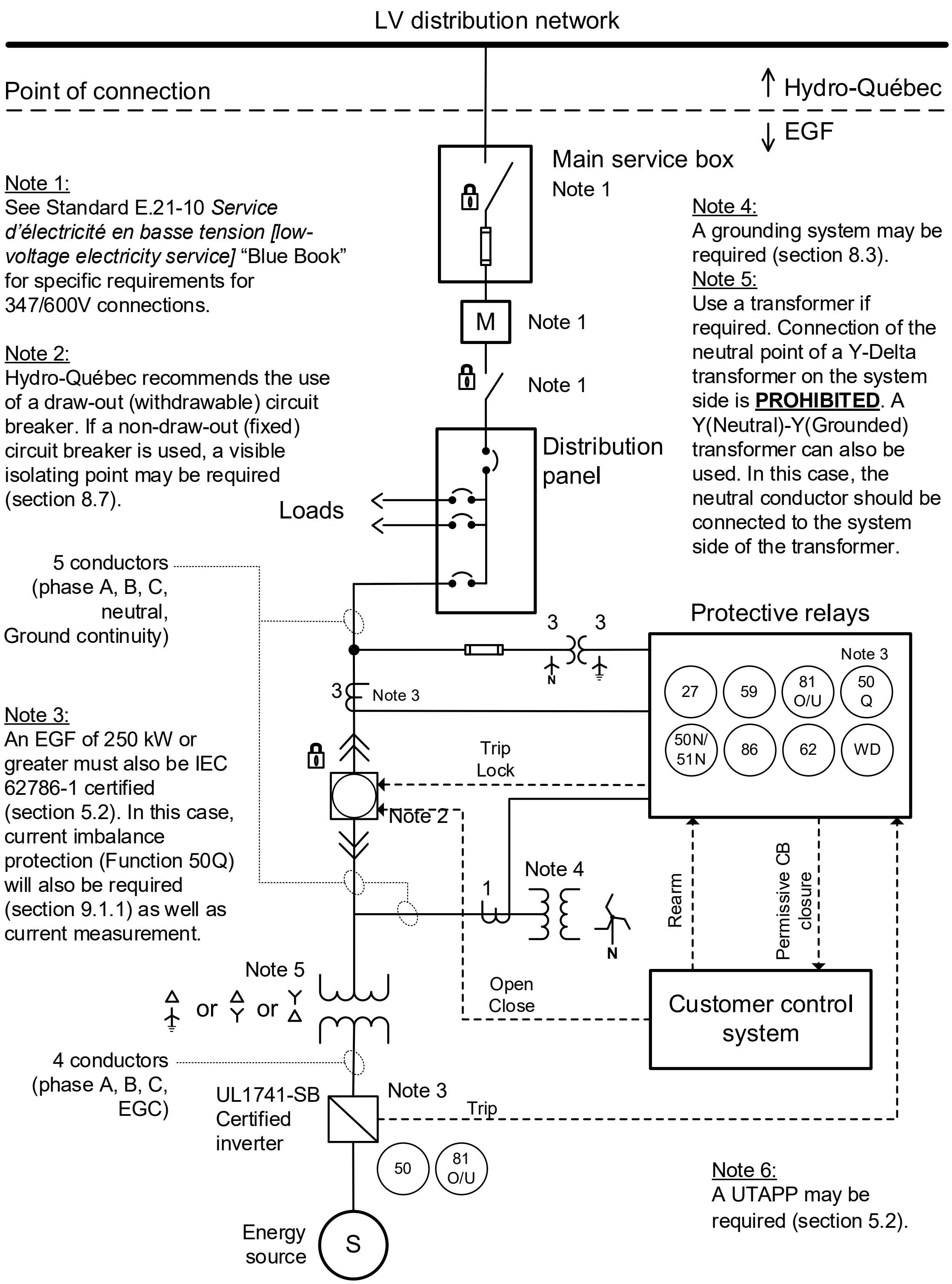


Figure 10: LV connection diagram for an EGF using a certified inverter, without neutral terminal, with or without Delta-Y(Grounded), Delta-Y or Y-Delta power transformer, equipped with a grounding transformer

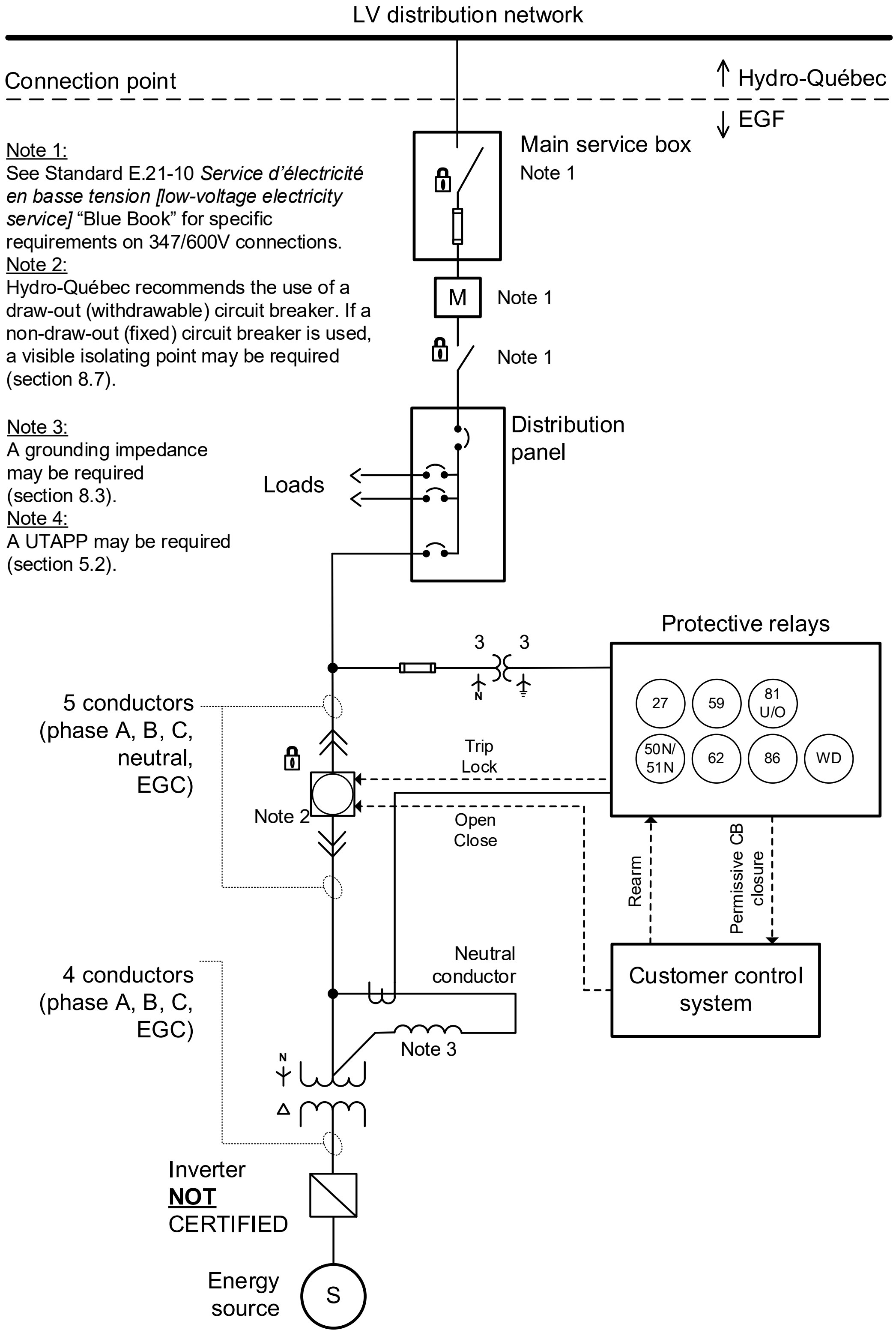
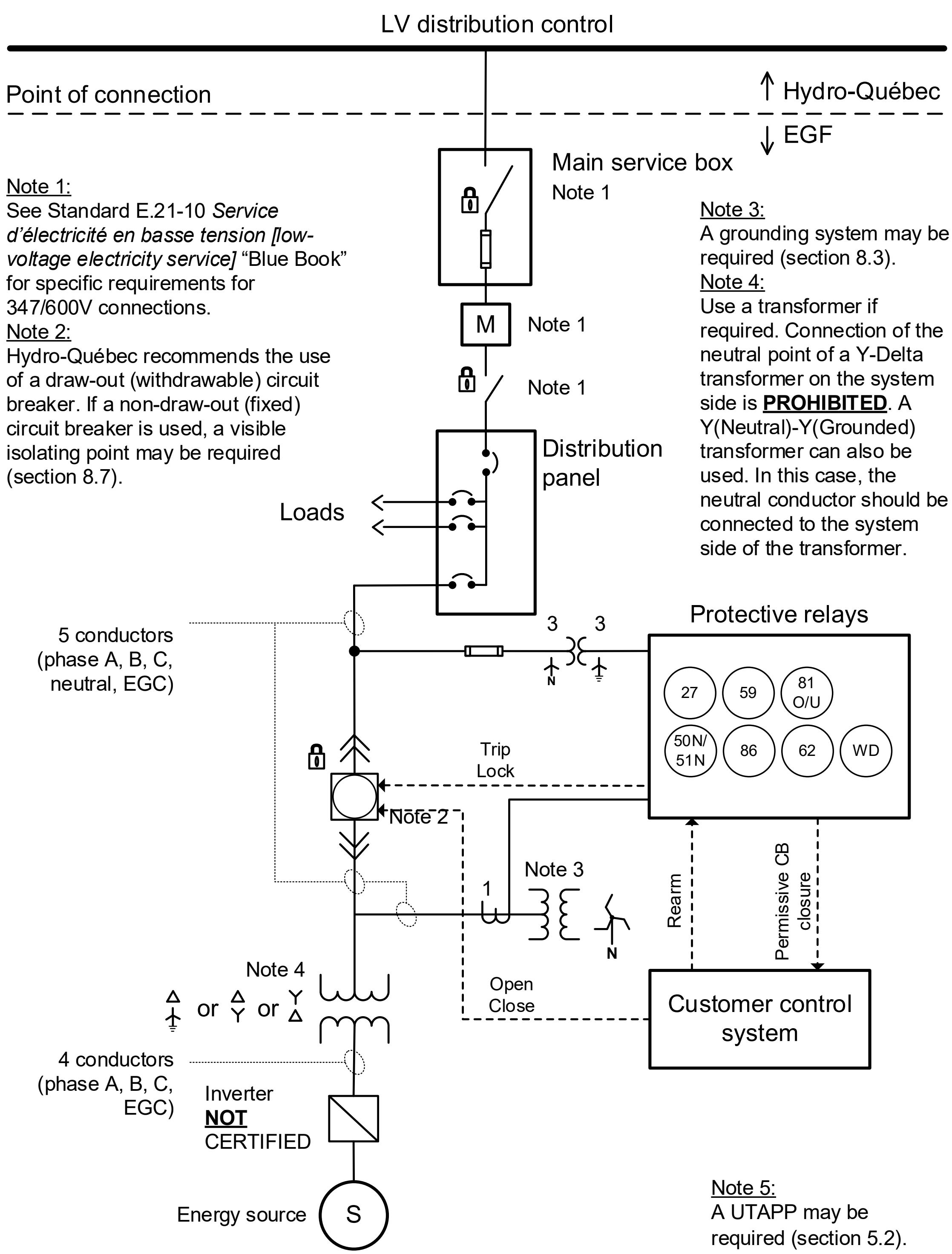


Figure 11: LV connection diagram for an EGF using non-certified inverter, without neutral terminal, with Y(Grounded)-Delta power transformer



Note 1:
See Standard E.21-10 *Service d'électricité en basse tension [low-voltage electricity service]* "Blue Book" for specific requirements for 347/600V connections.

Note 2:
Hydro-Québec recommends the use of a draw-out (withdrawable) circuit breaker. If a non-draw-out (fixed) circuit breaker is used, a visible isolating point may be required (section 8.7).

Note 3:
A grounding system may be required (section 8.3).

Note 4:
Use a transformer if required. Connection of the neutral point of a Y-Delta transformer on the system side is **PROHIBITED**. A Y(Neutral)-Y(Grounded) transformer can also be used. In this case, the neutral conductor should be connected to the system side of the transformer.

Note 5:
A UTAPP may be required (section 5.2).

Figure 12: LV Connection diagram for an EGF using an uncertified inverter, with or without a neutral terminal, with or without a Delta-Y(Grounded), Delta-Y or Y-Delta power transformer, equipped with a grounding transformer

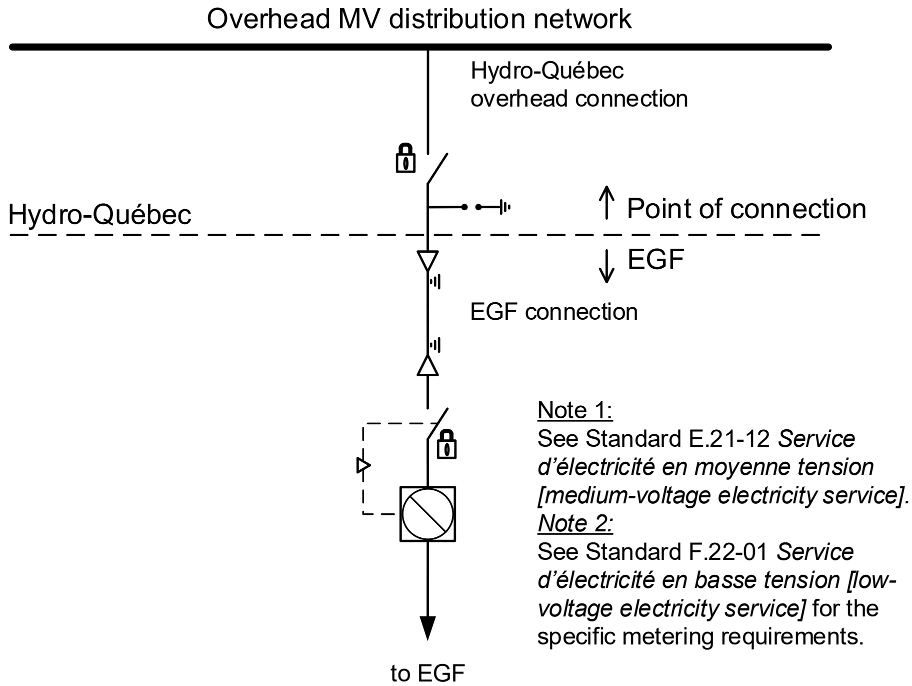


Figure 13: MV overhead-underground connection diagram

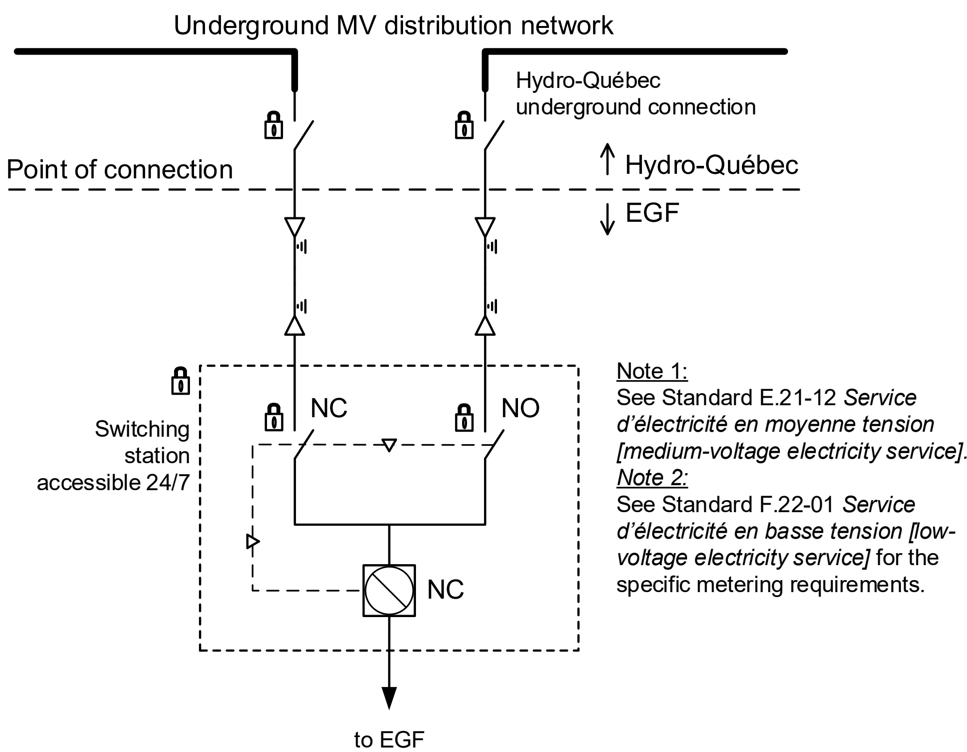
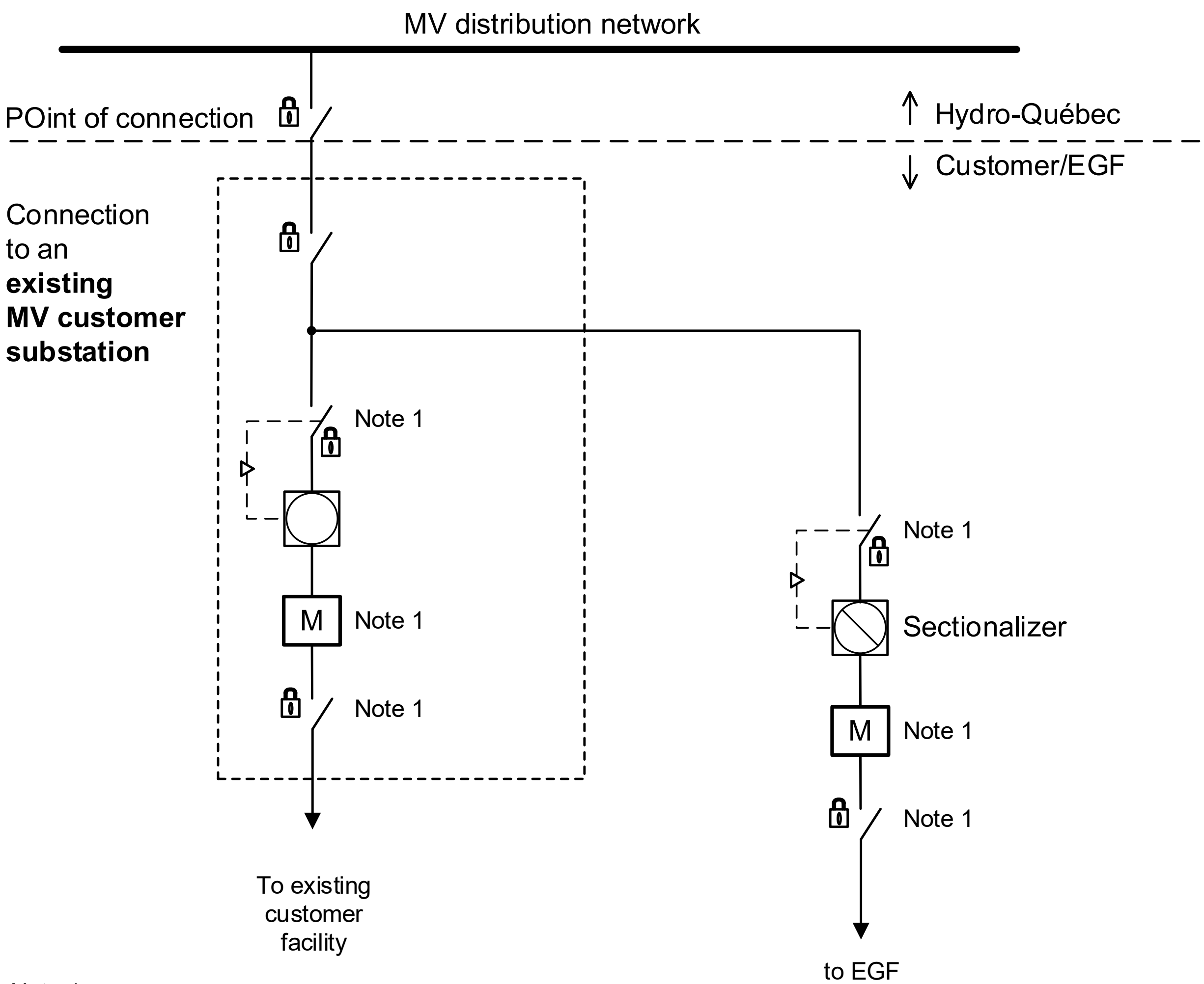


Figure 14: MV underground-underground connection diagram



Note 1:
See Standard E.21-12 *Service d'électricité en moyenne tension [medium-voltage electricity service].*
Note 2:
See Standard F.22-01 *Service d'électricité en basse tension [low-voltage electricity service]* for the specific metering requirements.

Figure 15: Connection diagram for an EGF connected inside an existing MV customer substation and requiring independent metering of the customer facility

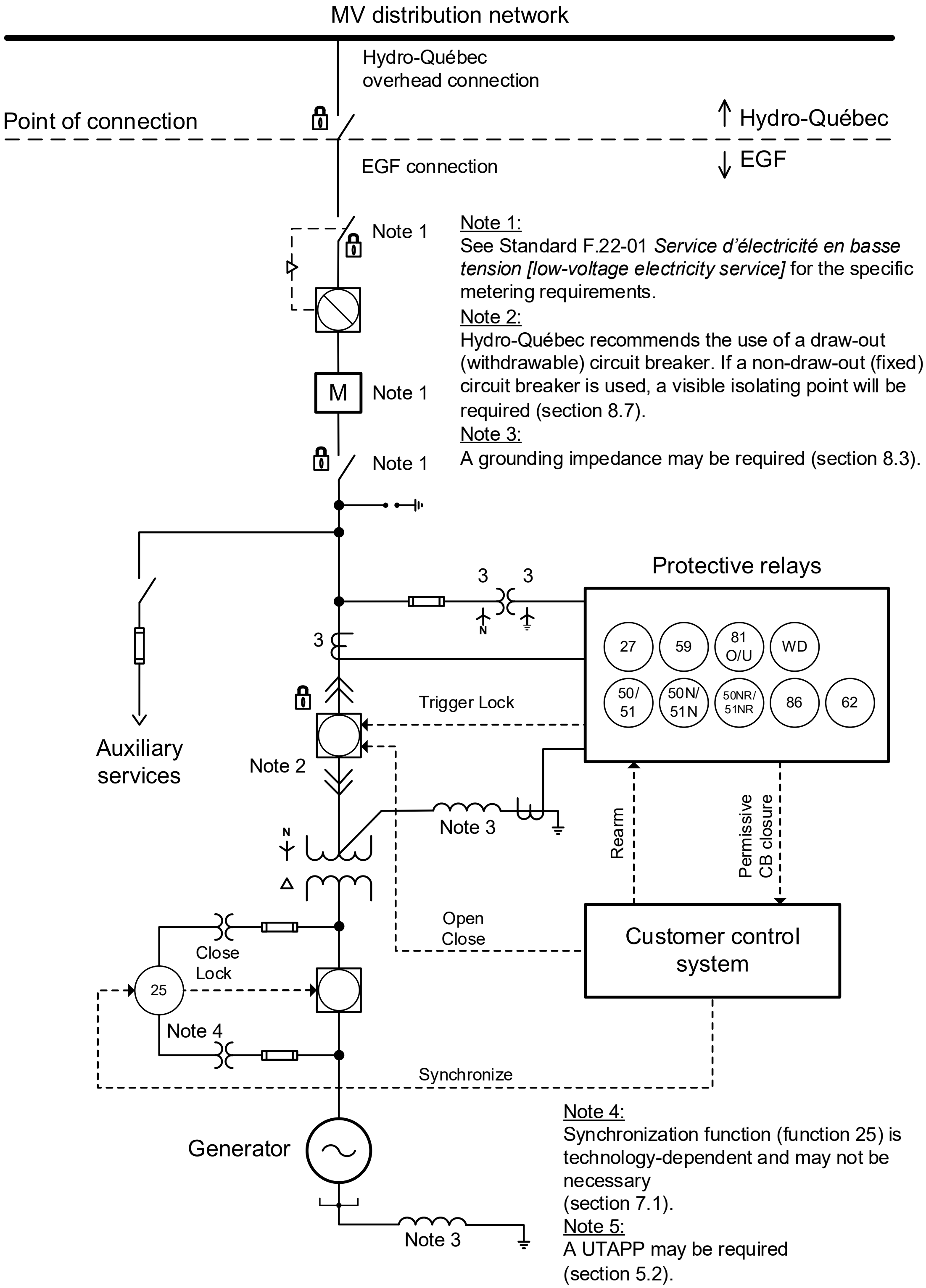


Figure 16: MV connection diagram for an EGF using a generator, with Y(Grounded)-delta power transformer, synchronized to BV

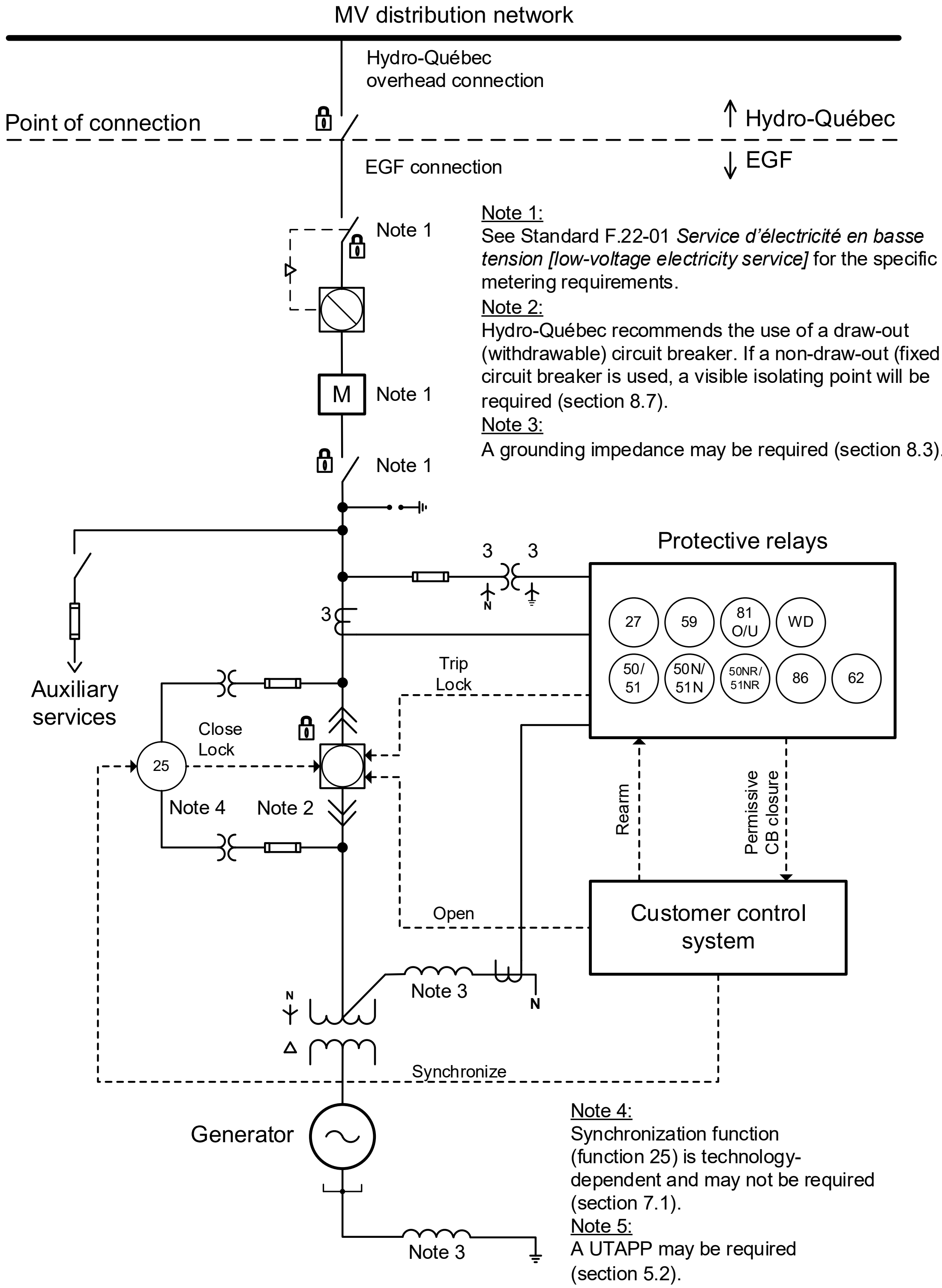


Figure 17: MV connection diagram for an EGF using a generator, with Y(Grounded)-delta power transformer, synchronized to MV

Title of guideline	Guideline number	Effective date YYYY-MM-DD
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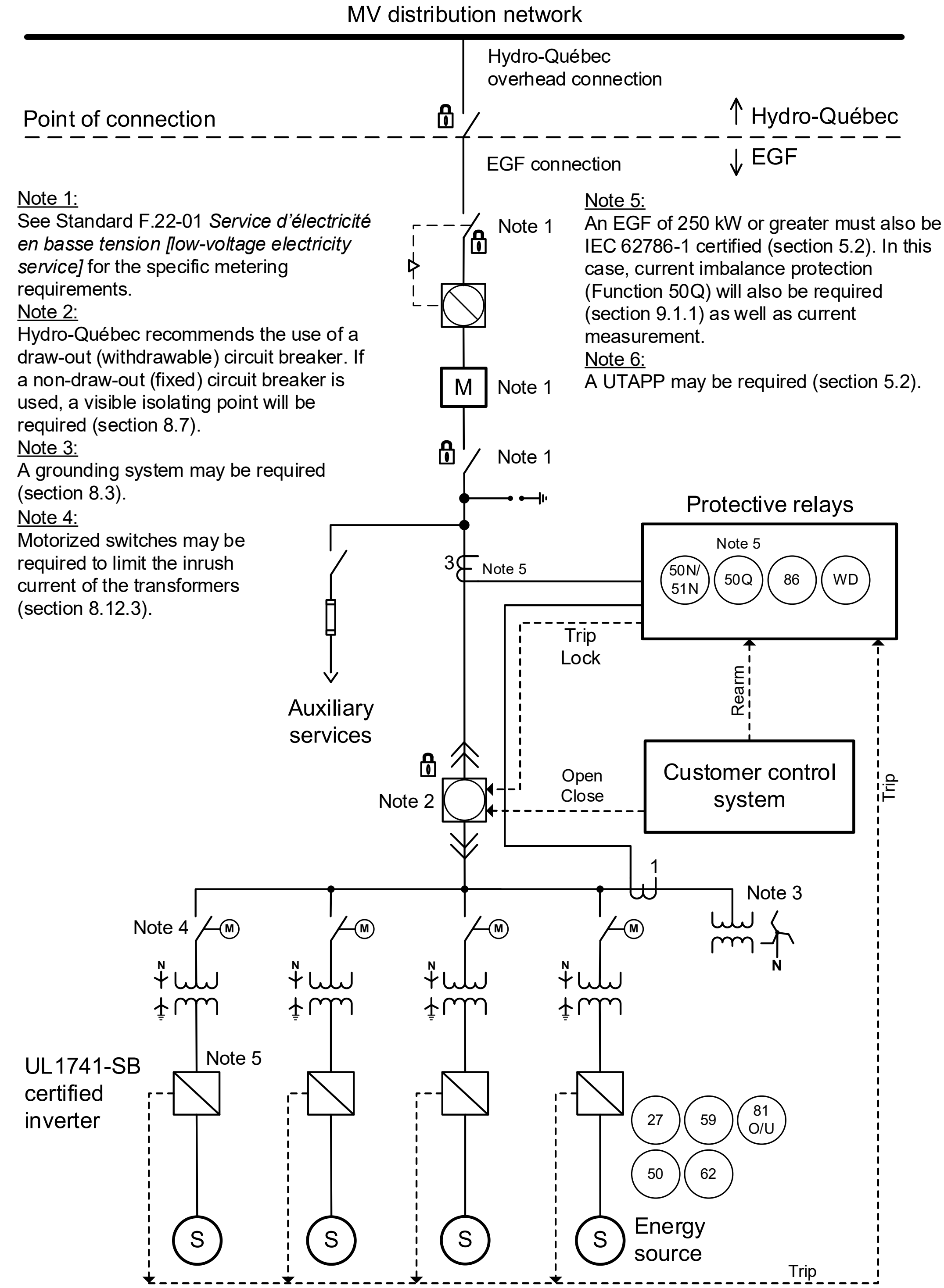


Figure 18: MV connection diagram for an EGF using certified three-phase inverters, with Y(Neutral)-Y(Grounded) power transformer

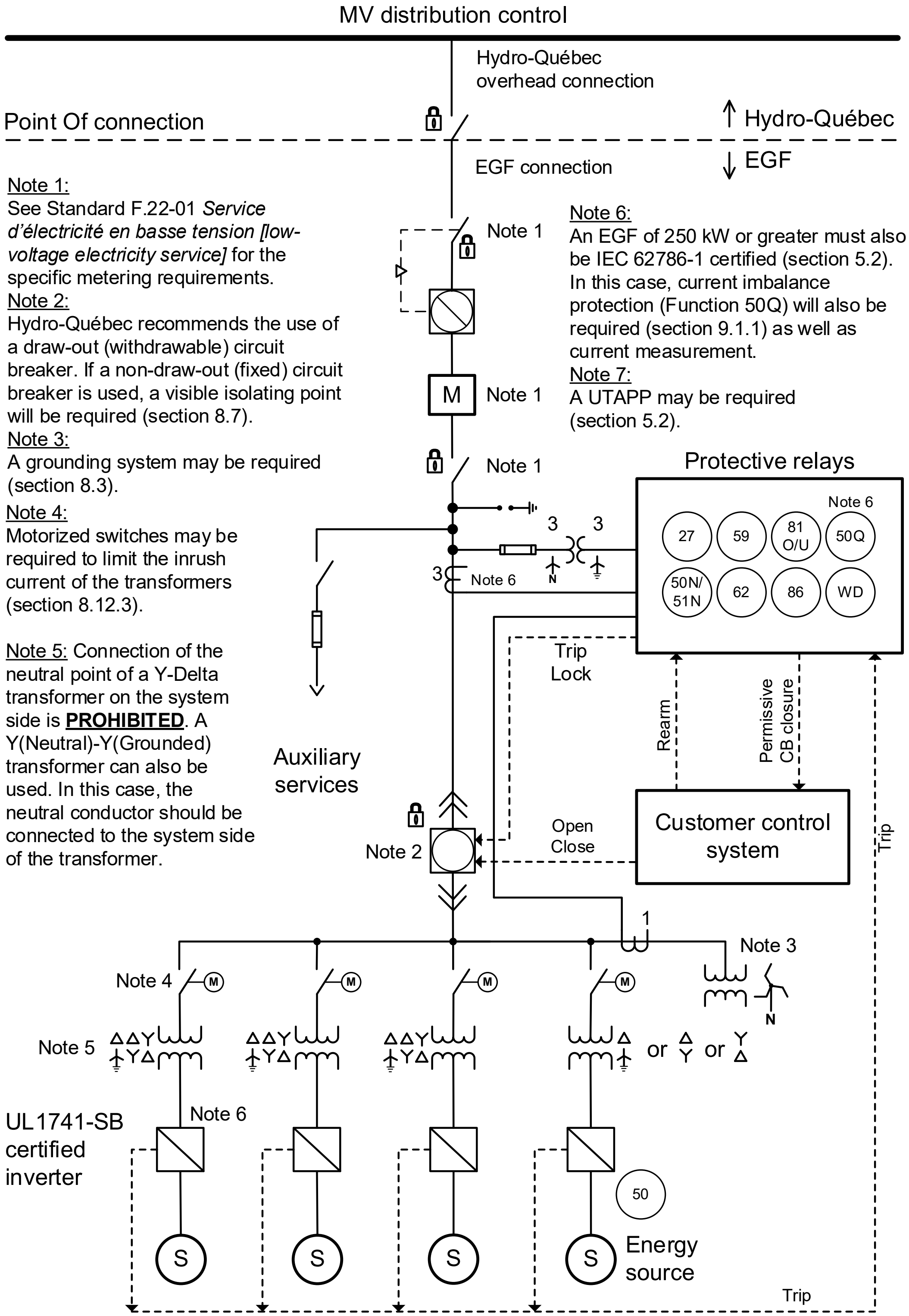


Figure 19: MV connection diagram of an EGF using three-phase certified inverters, with Delta-Y(Grounded), Delta-Y or Y-Delta power transformer, equipped with a grounding transformer

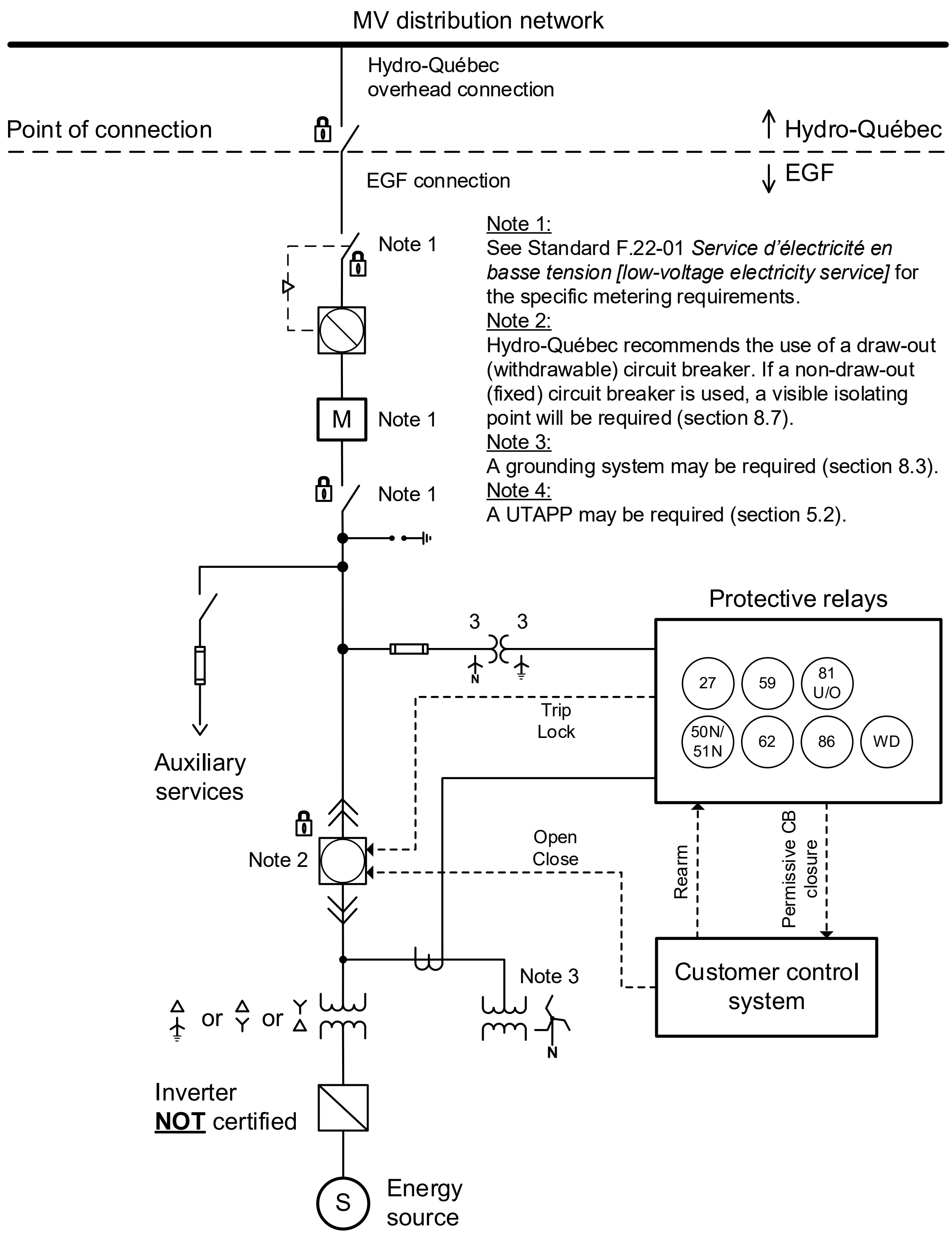
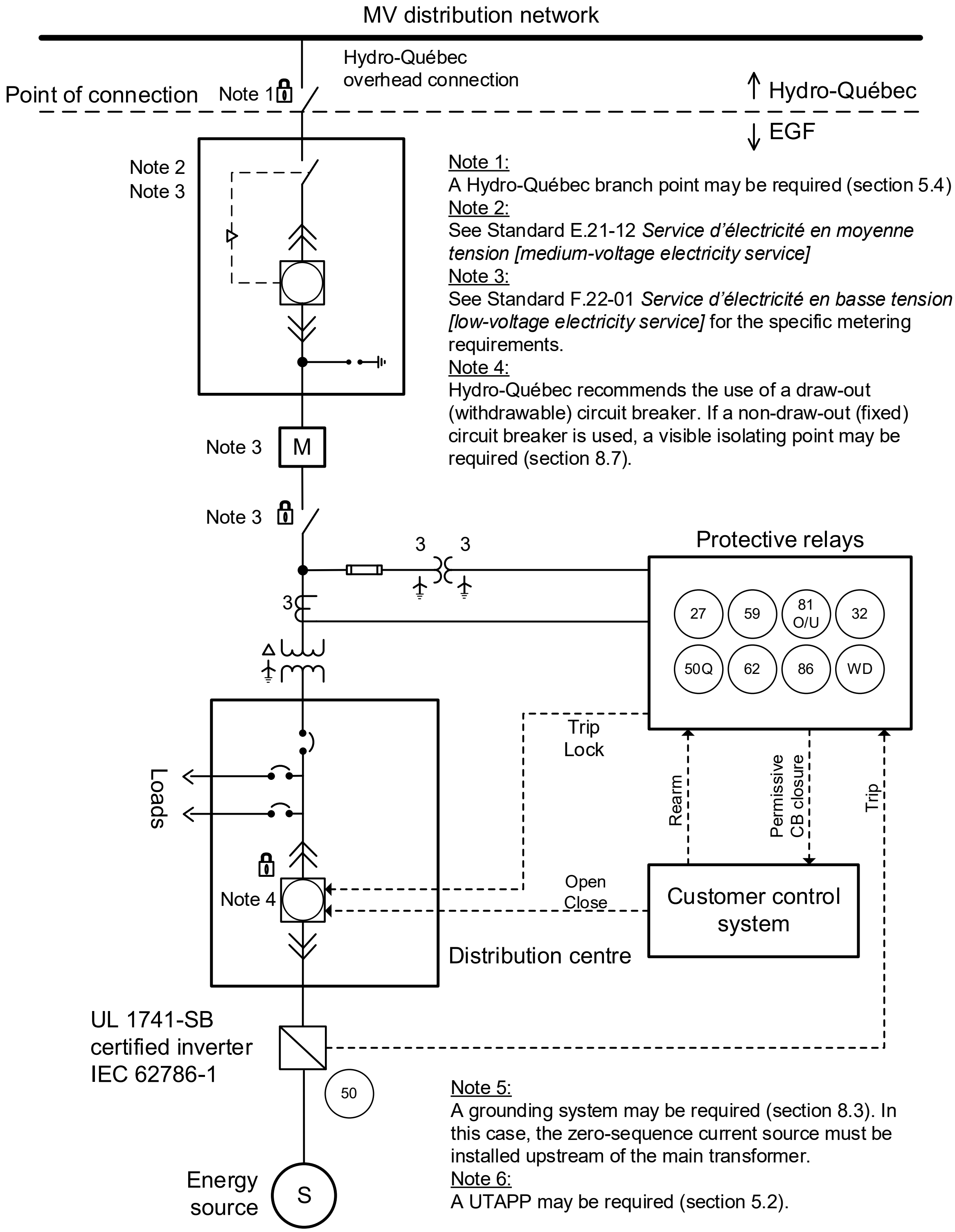


Figure 20: MV connection diagram for an EGF using an uncertified three-phase inverter, with Delta-Y(Grounded), Delta-Y or Y-Delta power transformer, equipped with a grounding transformer



Note 1:
A Hydro-Québec branch point may be required (section 5.4)

Note 2:
See Standard E.21-12 *Service d'électricité en moyenne tension [medium-voltage electricity service]*

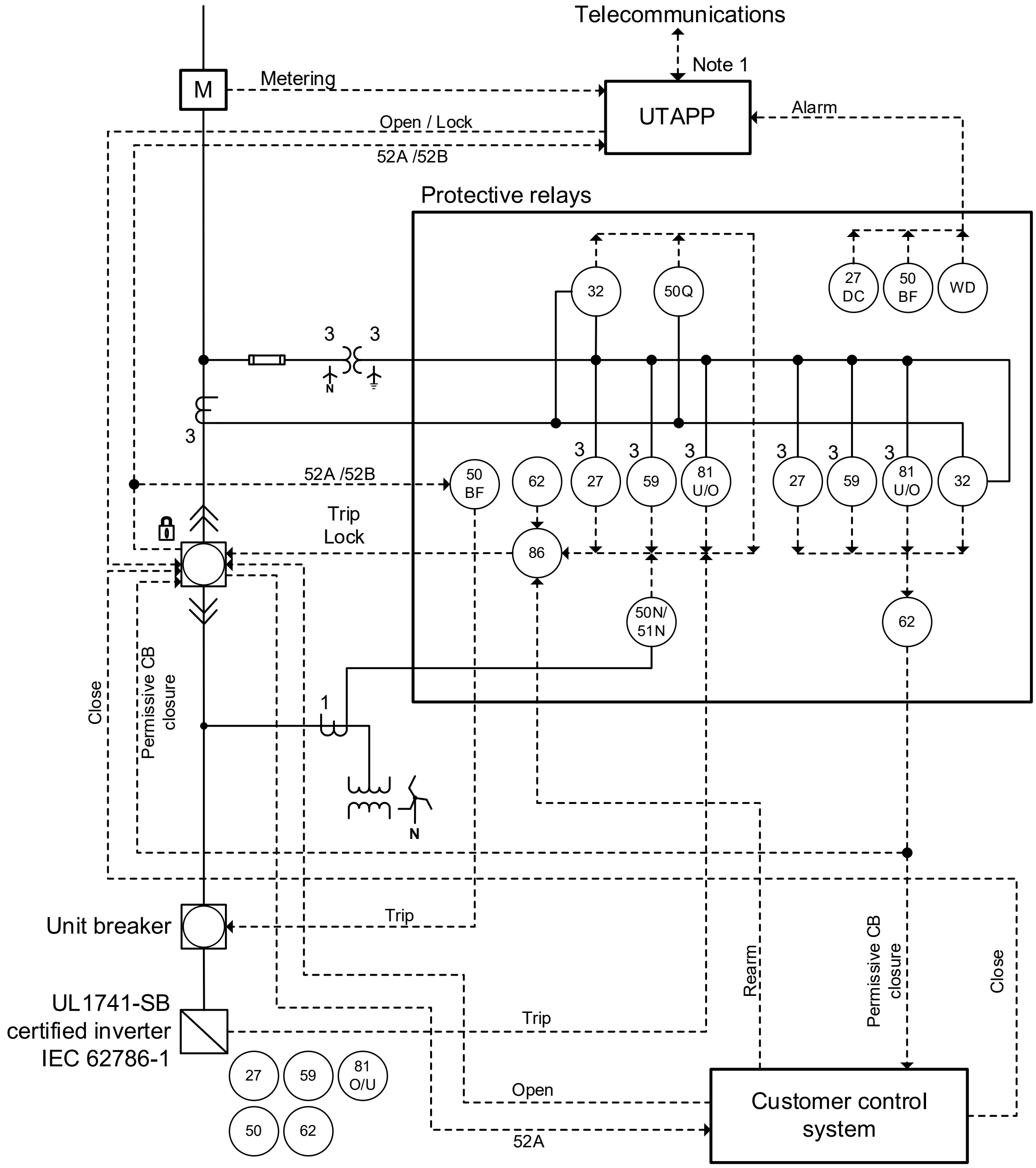
Note 3:
See Standard F.22-01 *Service d'électricité en basse tension [low-voltage electricity service]* for the specific metering requirements.

Note 4:
Hydro-Québec recommends the use of a draw-out (withdrawable) circuit breaker. If a non-draw-out (fixed) circuit breaker is used, a visible isolating point may be required (section 8.7).

Note 5:
A grounding system may be required (section 8.3). In this case, the zero-sequence current source must be installed upstream of the main transformer.

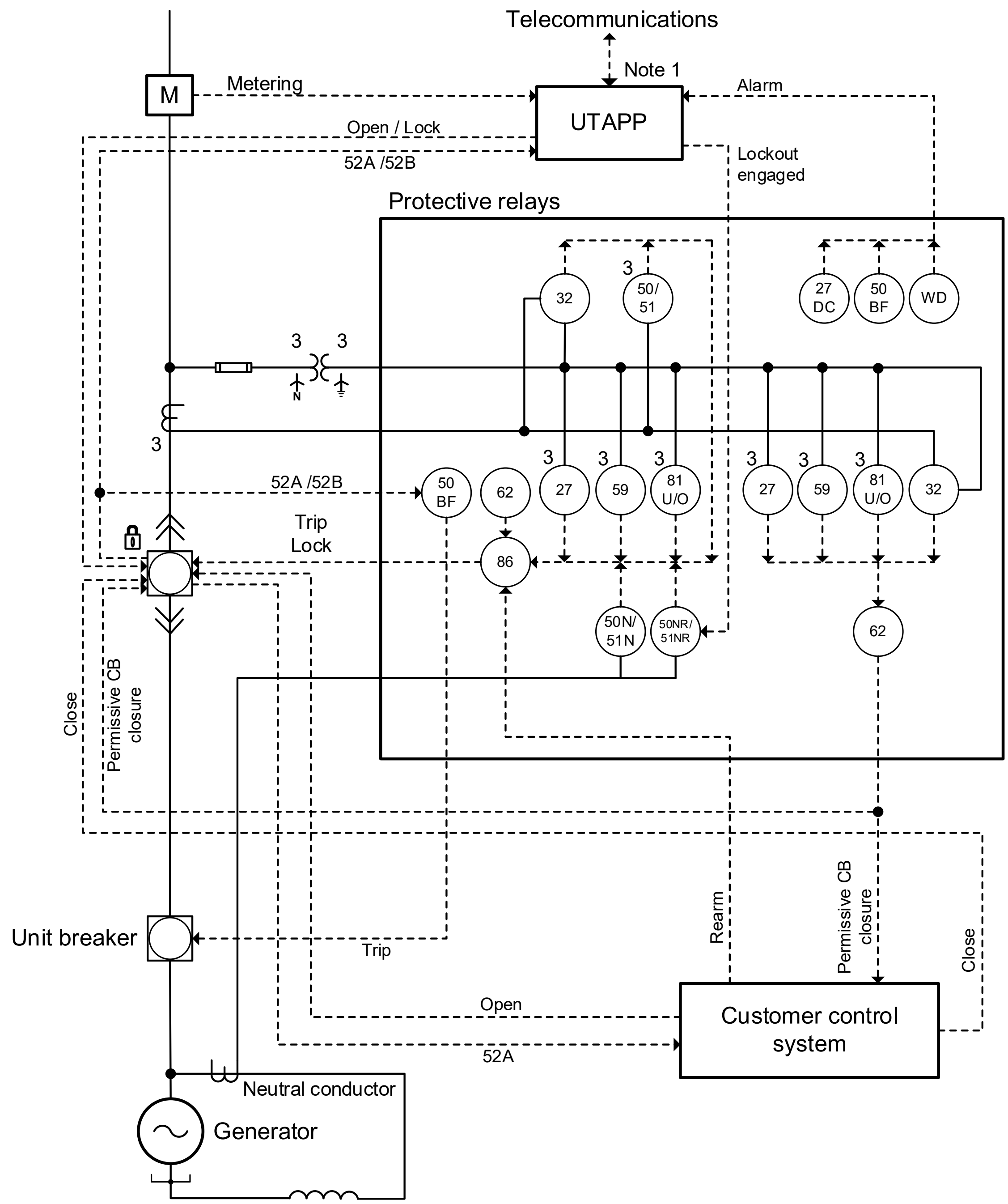
Note 6:
A UTAPP may be required (section 5.2).

Figure 21: MV connection diagram for an EGF with a capacity of 250 kW or greater using a certified three-phase inverter, installed at a Self-generation customer's premises



Note 1:
See Standard E.12-12 *Exigences pour l'installation et le raccordement de l'unité de télécommande et de télésignalisation des installations de production d'électricité raccordées au réseau de distribution d'Hydro-Québec [requirements for installing and connecting remote control and remote indication units for electricity generation facilities connected to the Hydro-Québec distribution system]* for specific UTAPP installation requirements.

Figure 22: Control and protection diagram for an EGF with a capacity of 250 kW or greater with certified inverter and UTAPP



Note 1:
See Standard E.12-12 *Exigences pour l'installation et le raccordement de l'unité de télécommande et de télésignalisation des installations de production d'électricité raccordées au réseau de distribution d'Hydro-Québec[requirements for installing and connecting remote control and remote indication units for electricity generation facilities connected to the Hydro-Québec distribution system]* for specific UTAPP installation requirements.

Control and protection diagram for an EGF equipped with a generator and UTAPP

Figure 23: Control and protection diagram for an EGF with a capacity of 250 kW or greater equipped with a generator and UTAPP

Appendix C

(For information purposes)

Design elements checklist for an EGF using IBRs installed at a Self-generation customer's premises

- ☐ UL1741-SB certified inverter (section 8.13.1)
- ☐ EGF compliant with Standard IEEE 2030 5 (section 10.1)
- ☐ If the connection is single phase, the maximum capacity is 40 kW (section 5.1)
- ☐ Power metering point upstream of the load Point of Connection in the customer facility (required especially when directional power protection [function 32] is used) (section 9.1.3 and 9.1.4)
- ☐ Three-phase power metering when the Hydro-Québec Point of Connection is three-phase (section 9.1.3 and 9.1.4)
- ☐ Validated power protection chain accuracy (metering, relays, and wiring) (required especially when directional power protection [function 32] is used) (section 9.8.5 and 9.8.6)
- ☐ All generation behind a single circuit breaker, the EGF main breaker (section 8.11)
- ☐ An overvoltage protection device is installed upstream of the EGF (section 8.10)
- ☐ An EGF used as a backup power source is equipped with an open transition transfer switch (section 12)
- ☐ The load in the installation is sufficient to eliminate the risk of temporary overvoltage in case of a phase-to-ground fault or a load rejection (section 5.3.2)
- ☐ Minimum load protection (section 9.1.3) or protection to limit injection of power is provided (section 9.1.4)

If the facility is connected to low voltage:

- ☐ Connection according to Figures 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 in Appendix B (section 5.10)
- ☐ Neutral terminal on inverter (section 8.13.2)
- ☐ No power transformer or Y(Neutral)-Y(Grounded) transformer 5 columns (section 8.12)
- ☐ 5-conductor power wiring (A, B, C, Neutral, equipment grounding conductor) (section 8.5)

If the facility is connected to medium voltage using a power transformer

Y(Neutral)-Y(Grounded) 5 columns:

- ☐ Connection according to Figure 18 in Appendix B(section 5.10)
- ☐ Neutral terminal on inverter (section 8.13.2)
- ☐ Power transformer or transformer Y(Neutral)-Y(Grounded) 5 columns (section 8.12)
- ☐ 5-conductor power wiring (A, B, C, Neutral, equipment grounding conductor) (section 8.5)

If the facility is connected at medium voltage using a Delta-Y power transformer

- ☐ Connection according to Figure 21 in Appendix C(section 5.10)
- ☐ Installation of voltage metering transformers for protection upstream of the power transformer (used for functions 27 and 59) (section 9.1.2)

In addition, for EGFs with a capacity of 250 kW or greater:

- ☐ IEC 62786-1 certified inverter (sections 5.2 and 8.13.1)
- ☐ UTAPP when required by Hydro-Québec (section 5.2)
- ☐ Three-phase inverter only (section 5.2)

- ☐ Power transformer inrush current mitigation is provided where required (section 8.12.3)
- ☐ Complies with immunity (no-trip) requirements (sections 6.4, 6.5, 6.6, 6.7 and 6.8)
- ☐ Complies with ride-through requirements (sections 6.4.1 and 6.7.2)
- ☐ Allows maximum voluntary ramp rate configuration (section 7.2.2)
- ☐ Calculation of grounding coefficient completed (section 5.3.1)
- ☐ PSS/E model available (section 5.11)
- ☐ EGF dual-control main circuit breaker (section 8.11)
- ☐ No-fail protection circuit design (section 9.6)
- ☐ Circuit breaker fault protection (50BF function) is present when the installed power of the EGF is greater than 5 MW (function 9.1.7)

In addition, when multifunction relays are required:

- ☐ 3 phase-to-neutral voltage transformers used only for HQ protection (section 9.7)
- ☐ 3 current transformers used only for HQ protection (section 9.7)
- ☐ Relay status monitoring contact (section 9.2)
- ☐ For EGFs with a capacity of 250 kW or greater: primary and backup protection are provided by different and distinct relays (section 9.2)
- ☐ 15-minute backup power supply (section 9.3)

In addition, when a zero-sequence current source is required:

- ☐ An additional grounding transformer is used (section 8.3)
- ☐ An external resistance/inductance is used to achieve a grounding coefficient of 0.8 (section 8.4)
- ☐ If possible, the zero-sequence impedance is adjusted so that the short-circuit phase-to-ground current at MV is less than 5A (section 9.1.1)

Design elements checklist for an EGF using IBRs and connected to LV or MV for simplified system connection

- ☐ UL1741-SB certified inverter (section 8.13.1)
- ☐ EGF compliant with Standard IEEE 2030.5 (section 10.1)
- ☐ If the connection is single phase, the maximum capacity is 40 kW (section 5.1)
- ☐ Neutral terminal on inverter (section 8.13.2)
- ☐ LV: No power transformer or transformer Y(Neutral)-Y (Ground) 5 columns (section 8.12)
- ☐ MV: Y(Neutral)-Y (Ground) power transformer 5 columns (section 8.12)
- ☐ 5-conductor power wiring (A, B, C, Neutral, equipment grounding conductor) (section 8.5)
- ☐ LV: Connection according to Figures 1, 2 or 4 in Appendix B (section 5.10)
- ☐ MV: Connection according to Figure 18 in Appendix B(section 5.10)
- ☐ All generation behind a single circuit breaker, the EGF main breaker (section 8.11)
- ☐ Overvoltage protection device installed upstream of the EGF (section 8.10)
- ☐ EGF used as backup power has an open transition transfer switch (section 12)

In addition, for EGFs with a capacity of 250 kW or greater:

- ☐ IEC 62786-1 certified inverter (sections 5.2 and 8.13.1)
- ☐ Three-phase inverter only (section 5.2)
- ☐ Power transformer inrush current mitigation is provided where required (section 8.12.3)
- ☐ UTAPP (section 5.2)
- ☐ Complies with immunity (no-trip) requirements (sections 6.4, 6.5, 6.6, 6.7 and 6.8)
- ☐ Complies with ride-through requirements (sections 6.4.1 and 6.7.2)
- ☐ Allows maximum voluntary ramp rate configuration (section 7.2.2)
- ☐ PSS/E model available (section 5.11)
- ☐ EGF dual-control main circuit breaker (section 8.11)
- ☐ No-fail protection circuit design (section 9.6)
- ☐ Calculation of the grounding coefficient completed (section 5.3.1)
- ☐ Circuit breaker fault protection (50BF function) is present when the installed power of the EGF is greater than 5 MW (function 9.1.7)

In addition, when multifunction relays are required:

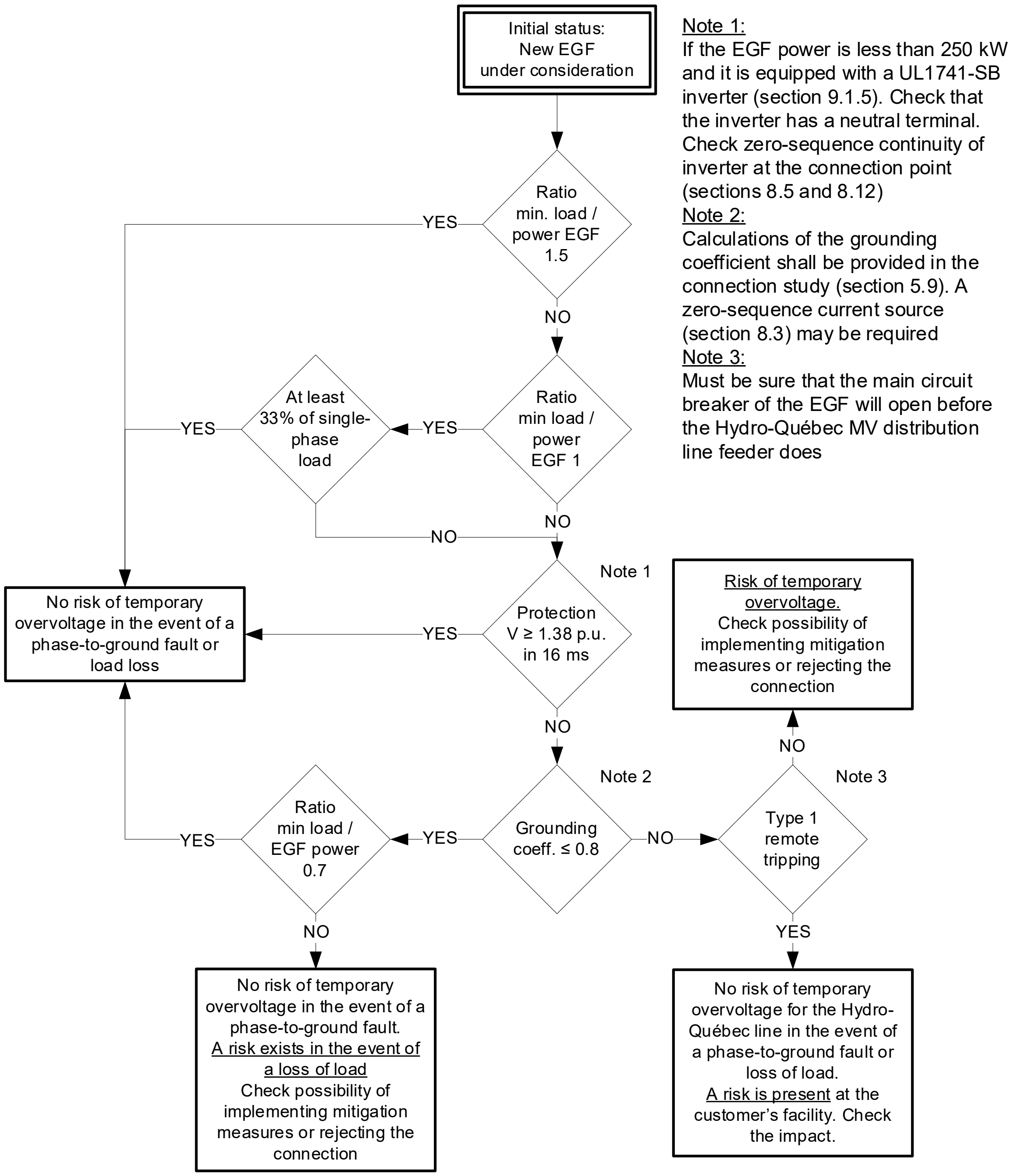
- ☐ 3 phase-to-neutral voltage transformers used only for HQ protection (section 9.7)
- ☐ 3 current transformers used only for HQ protection (section 9.7)
- ☐ Relay status monitoring contact (section 9.2)
- ☐ For EGFs with a capacity of 250 kW or greater: primary and backup protection are provided by different and distinct relays (section 9.2)
- ☐ 15-minute backup power supply (section 9.3)

In addition, when a zero-sequence current source is required:

- ☐ An additional grounding transformer is used (section 8.3)
- ☐ An external resistance/inductance is used to achieve a grounding coefficient of 0.8 (section 8.4)

Appendix D

Temporary overvoltage hazard analysis flowchart for connection of a Self-generation customer equipped with IBR



This figure is adapted from Figure 6-3 of EPRI report number 3002020130 *Effective Grounding for Inverter-Connected DER*.

Appendix E

(For information purposes)

Examples of safety labels and notices

List of figures

Figure 1 : Lockout tag as requested by Hydro-Québec

Title of guideline	Guideline number	Effective date YYYY-MM-DD
Technical requirements for distributed generation interconnection to the Hydro-Québec distribution system	**E.12-01**	**2025-11-17**

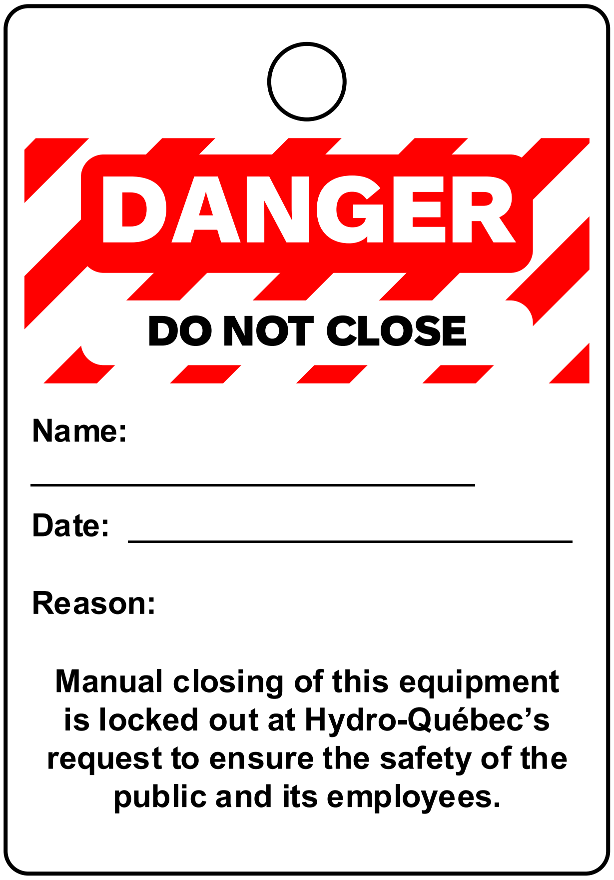


Figure 2: EGF main circuit breaker manual close lockout tag

CAUTION

ELECTROCUTION HAZARD

An electricity generating facility is present in this building.

THIS CABINET IS POWERED BY TWO SOURCES

It is powered by both the Hydro-Québec system and the electricity generating facilities.

Figure 3: Notice of presence of an EGF

DISCONNECT POINT

ELECTRICITY GENERATING FACILITY

Operating voltage: ________ Volts AC

Operating current: ________ Amp. AC

Figure 4: Safety warning to affix to EGF disconnect point

MAIN CIRCUIT BREAKER

ELECTRICITY GENERATING FACILITY

This system is used to ensure the safety of the public and of Hydro-Québec employees.

It is PROHIBITED to modify it without Hydro-Québec's written authorization.

Figure 5: EGF main circuit breaker safety warning

DANGER

ELECTROCUTION HAZARD

Lockout of manual circuit breaker controls

To ensure the safety of the public and of Hydro-Québec employees:

It is PROHIBITED to use the manual closing control of the circuit breaker.

Figure 6: Warning to be applied to the EGF main circuit breaker when its manual controls must be locked out

PROTECTIVE RELAY
ELECTRICITY GENERATING FACILITY

This system is used to ensure the safety of the public and of Hydro-Québec employees.

It is PROHIBITED to modify it without Hydro-Québec's written authorization.

Figure 7: Warning to be applied to EGF protection relays

UTAPP
ELECTRICITY GENERATING FACILITY

This system is used to ensure the safety of the public and of Hydro-Québec employees.

It is PROHIBITED to modify it without Hydro-Québec's written authorization.

Figure 8: Warning to be applied to the UTAPP of the EGF

PROTECTION SYSTEMS
ELECTRICITY GENERATING FACILITY

This system is used to ensure the safety of the public and of Hydro-Québec employees.

It is PROHIBITED to modify it without Hydro-Québec's written authorization.

Figure 9: Warning to be applied to EGF protection systems

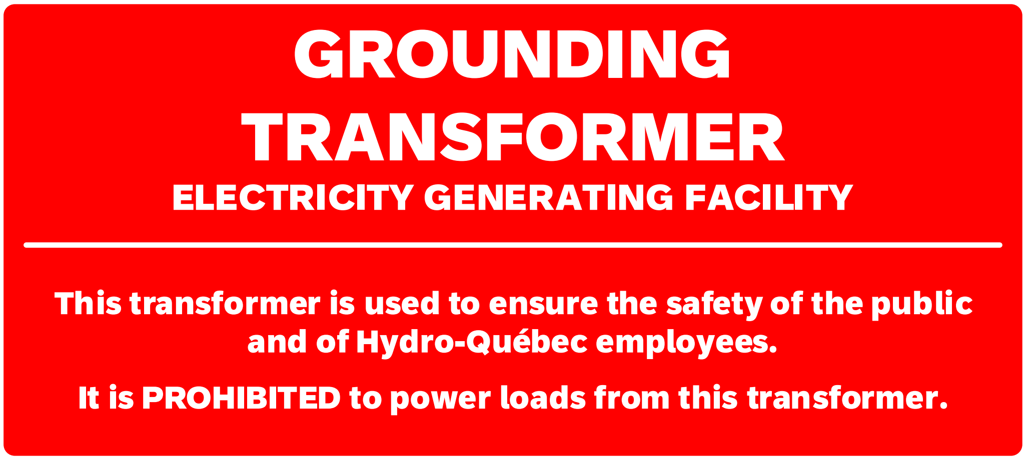


Figure 10: Warning to be applied to the grounding transformer of an EGF

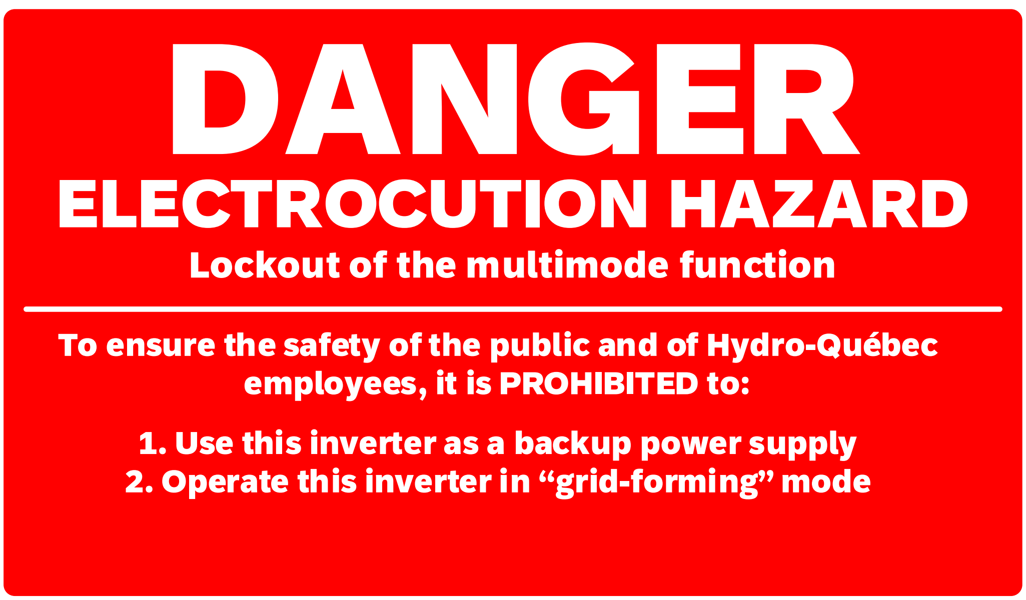


Figure 11: Warning to be affixed to a multimode inverter with a single terminal

Appendix F

(For information purposes)

Contents of the EGF Facilities Study

The EGF owner must submit to Hydro-Québec an EGF Facilities Study signed by an engineer. In order to conduct the Facilities Study, Hydro-Québec provides a study template. The following is an example of the content.

BACKGROUND – Hydro-Québec
NOTE ON THE DOCUMENT
APPENDICES
SUMMARY OF TABLES
1 INTRODUCTION
1.1 Electricity generating facility owner contact information
1.2 Location of electricity generating facility
1.3 Facilities Study signatory contact information
1.4 General description
1.5 Assignment
1.6 Exclusions
1.7 Exclusions
1.8 Future developments
1.9 Important dates
1.10 Site location map
1.11 Application processing steps
2 CHARACTERISTICS OF THE FACILITY
2.1 Installation
2.2 Production forecasts
2.3 Characteristics of the equipment
2.4 Simulation models
2.5 Operation
2.6 Maintenance
2.7 Lockout
2.8 Posting of safety notices
3 VOLTAGE- AND FREQUENCY-RELATED REQUIREMENTS
3.1 Voltage fluctuations
3.2 Harmonic distortion
3.3 Injection of direct current
3.4 Immunity and ride-through (voltage events, frequency, etc.)
4 EGF BEHAVIOUR-RELATED REQUIREMENTS
4.1 Startup conditions
4.2 Synchronization tolerances
4.3 Synchronization voltage
4.4 Design power factor
4.5 Maximum ramp rates for active power ramp-ups and ramp-downs
4.6 Energy storage system failure recovery
4.7 Active power regulation (Watts)
4.8 Reactive power regulation (Vars)
4.9 Short-circuit current contribution
4.10 Contribution to temporary overvoltages
5 REQUIREMENTS REGARDING EGF EQUIPMENT
5.1 Compliance with neutral system
5.2 Zero-sequence current source and ground impedance or resistance
5.3 Power wiring
5.4 Auxiliary services

Appendix G:

(For information purposes)

Overlay graphs showing the ride-through requirements and protection thresholds.

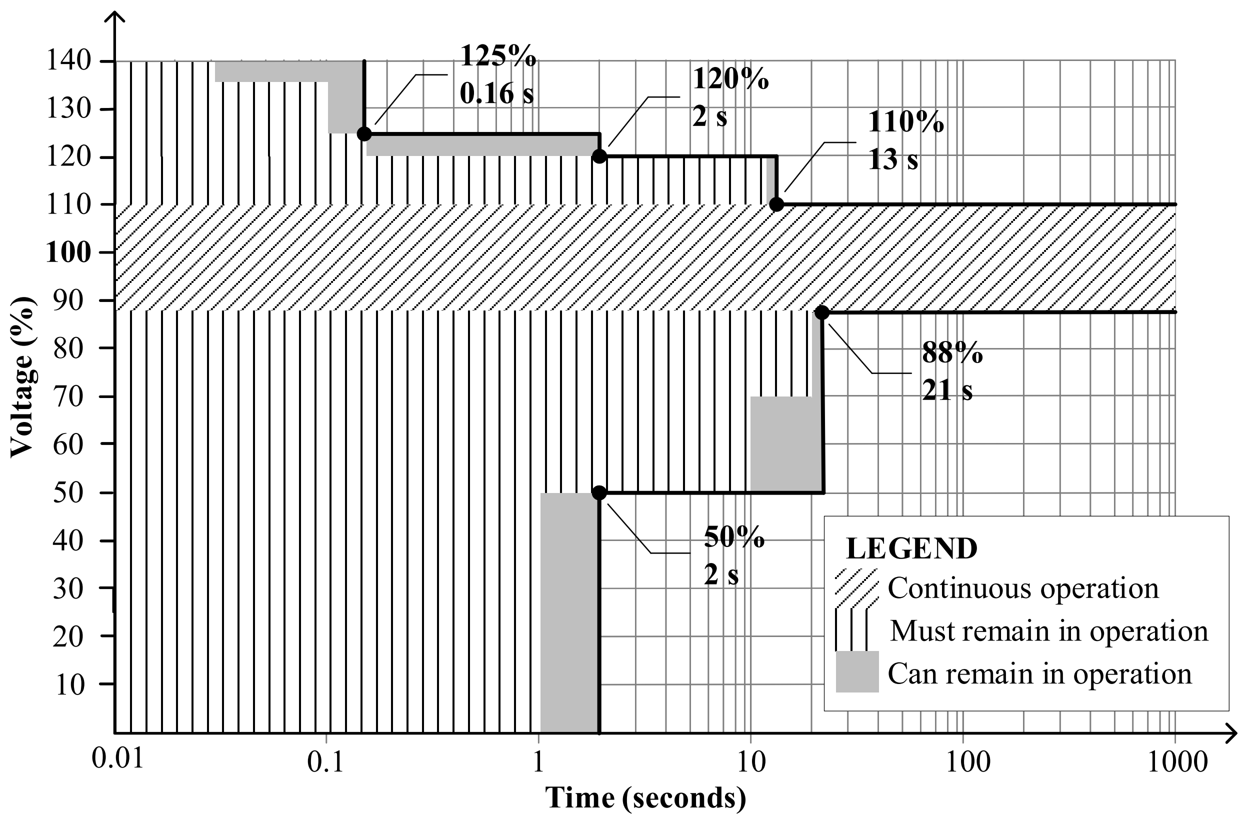


Figure 1: Voltage protection trip settings and EGF undervoltage and overvoltage ride-through

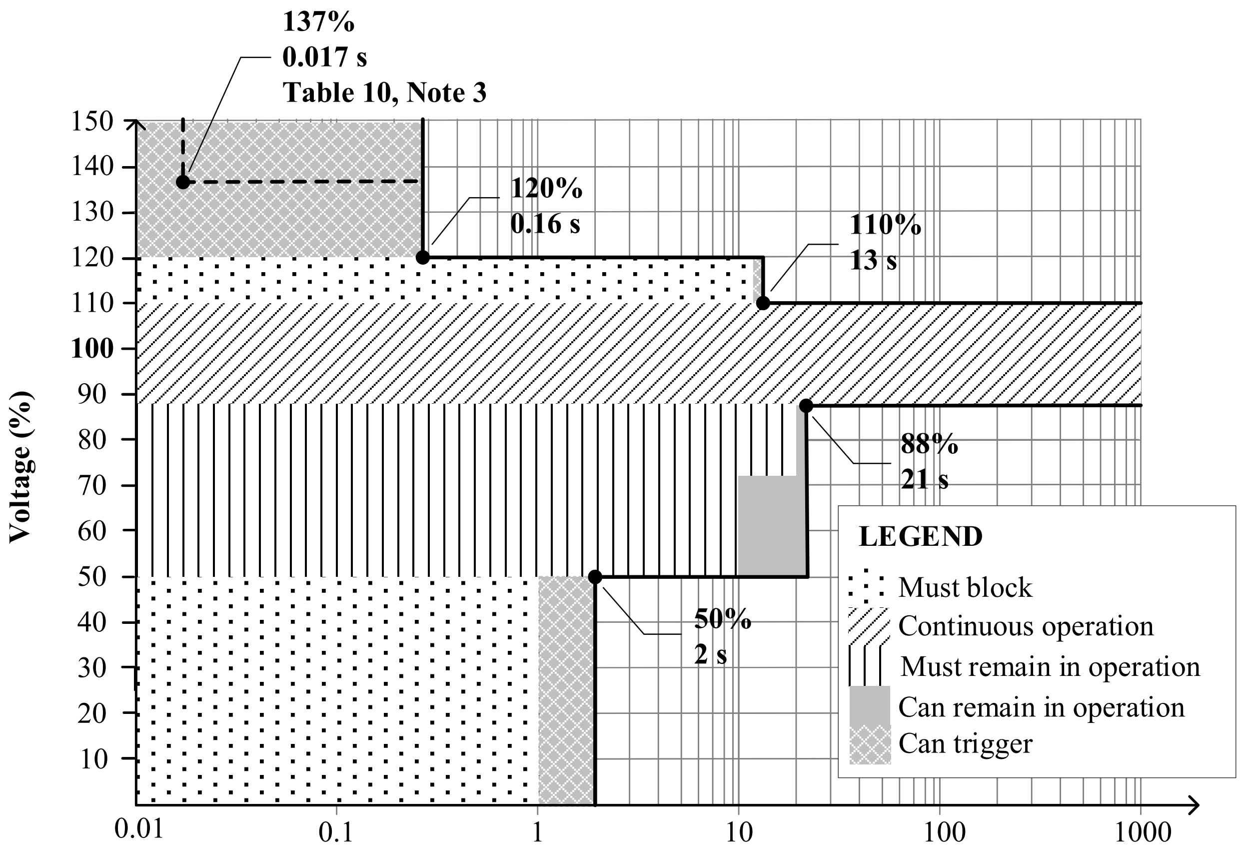


Figure 2: Voltage protection trip settings and undervoltage and overvoltage ride-through of an EGF of less than 250 kW using IBRs and a UL1741-SB certified inverter

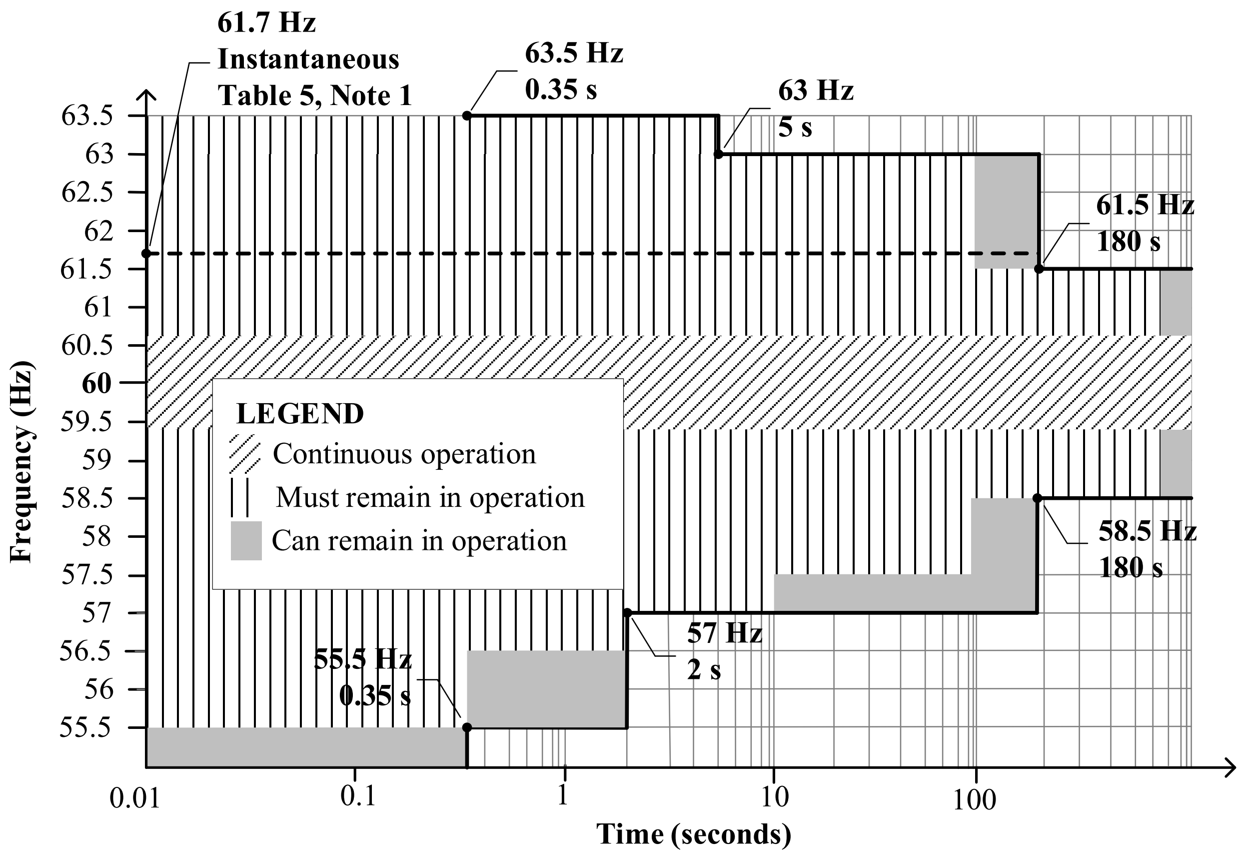


Figure 3: Frequency protection trip settings and frequency variation ride-through of an EGF

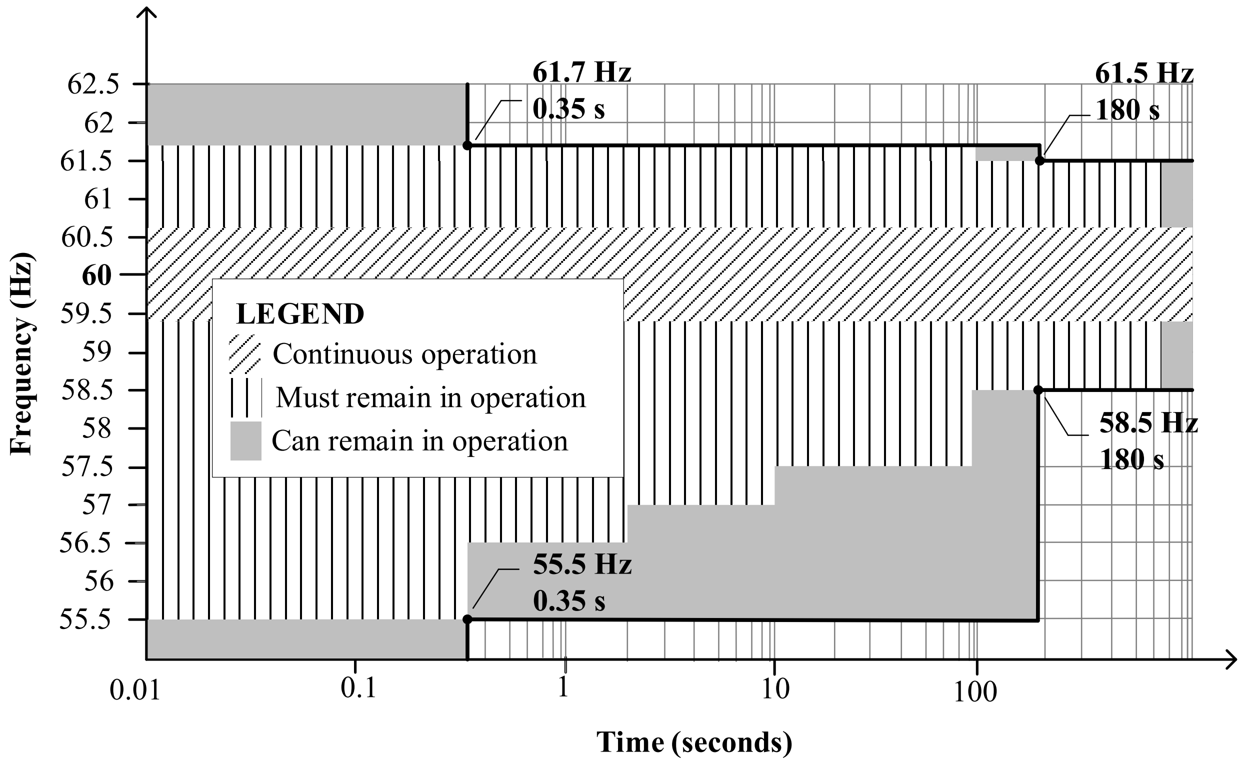


Figure 4: Frequency protection trip settings and frequency variation ride-through of an or EGFs of less than 250 kW using IBRs and a UL1741-SB certified inverter

Appendix H:

Values of numerical variables required for the application of IEC 62786-1 Distributed energy resources connection with the grid – Part 1: General requirements

Variables	Valeur	Unité	Définition
4.4.2 Operating frequency range			
P_{th-fd}	250	kW	Power thresold for frequency deviation
f_{min1}	59,4	Hz	Continuous operating minimum frequency
f_{max1}	60,6	Hz	Continuous operating maximum frequency
f_{min2}	55,5	Hz	Limited operating minimum frequency
f_{max2}	61,7	Hz	Limited operating maximum frequency
T_{f1}	660	s	Limited operating frequency minimum time
4.4.3 Operating voltage range			
P_{th-vd}	250	kW	Power thresold for voltage deviation
U_{min1}	0,88	per unit	Continuous operating minimum voltage
U_{max1}	1,10	per unit	Continuous operating maximum voltage
U_{min2}	0,5	per unit	Limited operating minimum voltage
U_{max2}	1,2	per unit	Limited operating maximum voltage
T_{u1}	21	s	Limited operating voltage disconnection time
T_{u2}	1	s	time
4.5.2 Rate of change of frequency (ROCOF) immunity			
$ROCOF_{hi}$	4	Hz/s	Higher rate of change of frequency threshold
$ROCOF_{lo}$	1,25	Hz/s	Lower rate of change of frequency threshold
$t_{ROCOFlo}$	2,00	s	Minimum withstand violation time for higher rate of change of frequency threshold
$t_{ROCOFhi}$	0,5	s	Minimum withstand violation time for lower rate of change of frequency threshold
4.5.2 Instantaneous ride through capability requirements			
f_{max}		Hz	Continuous operation maximum frequency
T_f		s	Maximum frequency duration time

4.5.3 Undervoltage ride through (UVRT) requirements			
U_1	0,05	per unit	Undervoltage ride through - voltage value 1
U_2	0,25	per unit	Undervoltage ride through - voltage value 2
U_3	0,75	per unit	Undervoltage ride through - voltage value 3
U_4	0,85	per unit	Undervoltage ride through - voltage value 4
U_5	0,85	per unit	Undervoltage ride through - voltage value 5
U_6	0,9	per unit	Undervoltage ride through - voltage value 6
t_1	0,25	s	Undervoltage ride through - time value 1
t_2	1	s	Undervoltage ride through - time value 2
t_3	2	s	Undervoltage ride through - time value 3
t_4	2	s	Undervoltage ride through - time value 4
t_5	30	s	Undervoltage ride through - time value 5
t_6	30	s	Undervoltage ride through - time value 6
S_{rec}	0,9	per unit	Proportion of pre-fault output power required after a fault is cleared
T_{rec}	1	s	Duration time after a fault is cleared when proportion of pre-fault output power is required
4.5.4 Overvoltage ride through (OVRT) requirements			
U_1	1,32	per unit	Overvoltage ride through - voltage value 1
U_2	1,25	per unit	Overvoltage ride through - voltage value 2
U_3	1,25	per unit	Overvoltage ride through - voltage value 3
U_4	1,2	per unit	Overvoltage ride through - voltage value 4
U_5	1,15	per unit	Overvoltage ride through - voltage value 5
U_6	1,1	per unit	Overvoltage ride through - voltage value 6
t_1	0,1	s	Overvoltage ride through - time value 1
t_2	0,1	s	Overvoltage ride through - time value 2
t_3	2	s	Overvoltage ride through - time value 3
t_4	2	s	Overvoltage ride through - time value 4
t_5	12	s	Overvoltage ride through - time value 5
t_6	12	s	Overvoltage ride through - time value 6
4.5.5 Rapid phase angle change immunity			
$Phase_{max-1p}$	60	deg	Rapid phase angle change immunity to single-phase fault
$Phase_{max-3p}$	20	deg	Rapid phase angle change immunity to three-phase fault
4.6 Active power response to frequency deviation			
P_{th-apc}	250	kW	Power thresold for active power control
f_n	60	Hz	Nominal network Frequency
Δf		Hz	Active power control dead-band for high frequency
G_{pu}		per unit	Active power control gradient for high frequency
$\Delta f'$		Hz	Active power control dead-band for low frequency
G'_{pu}		per unit	Active power control gradient for low frequency
4.7.2 Voltage support by reactive power			
P_{th-rp}	250	kW	Power thresold for reactive power

4.7.3 Reactive power control modes			
$Q = f(U)_{enable}$	YES	yes/no	Reactive power control - volt-var - enabled
$Q = f(U)_{priority}$	2	{1,8}	Reactive power control - volt-var - priority
$\cos(\varphi) = f(U)_{enable}$	NO	yes/no	Reactive power control - cos(phi)=f(U) - enabled
$\cos(\varphi) = f(U)_{priority}$		{1,8}	Reactive power control - cos(phi)=f(U) - priority
$Q = f(P)_{enable}$	NO	yes/no	Reactive power control - Q=f(P) - enabled
$Q = f(P)_{priority}$		{1,8}	Reactive power control - Q=f(P) - priority
$\cos(\varphi) = f(P)_{enable}$	NO	yes/no	Reactive power control - cos(phi)=f(P) - enabled
$\cos(\varphi) = f(P)_{priority}$		{1,8}	Reactive power control - cos(phi)=f(P) - priority
$Q = constant_{enable}$	NO	yes/no	Reactive power control - constant Q - enabled
$Q = constant_{priority}$		{1,8}	Reactive power control - constant Q - priority
$\cos(\varphi) = constant_{enable}$	YES	yes/no	Reactive power control - constant cos(phi) - enabled
$\cos(\varphi) = constant_{priority}$	3	{1,8}	Reactive power control - constant cos(phi) - priority
$Q = remote_{enable}$	NO	yes/no	Reactive power control - remote Q - enabled
$Q = remote_{priority}$		{1,8}	Reactive power control - remote Q - priority
$\cos(\varphi) = remote_{enable}$	YES	yes/no	Reactive power control - remote cos(phi) - enabled
$\cos(\varphi) = remote_{priority}$	1	{1,8}	Reactive power control - remote cos(phi) - priority
4.7.4 Voltage related active power control (volt-watt)			
P_{th-vwm}	250	kW	Power thresold for volt-watt mode
U_{min2}		per unit	Voltage related active power control - Limited operating minimum voltage
U_{min1}		per unit	Voltage related active power control - Continuous operating minimum voltage
U_{nom}		per unit	Nominal network Voltage
U_{max1}		per unit	Voltage related active power control - Continuous operating maximum voltage
U_{max2}		per unit	Voltage related active power control - Limited operating maximum voltage
P_{max}		per unit	Voltage related active power control - Limited operating maximum power
P_{nom}		per unit	Voltage related active power control - Continuous operating nominal power
P_{min}		per unit	Voltage related active power control - Limited operating minimum power

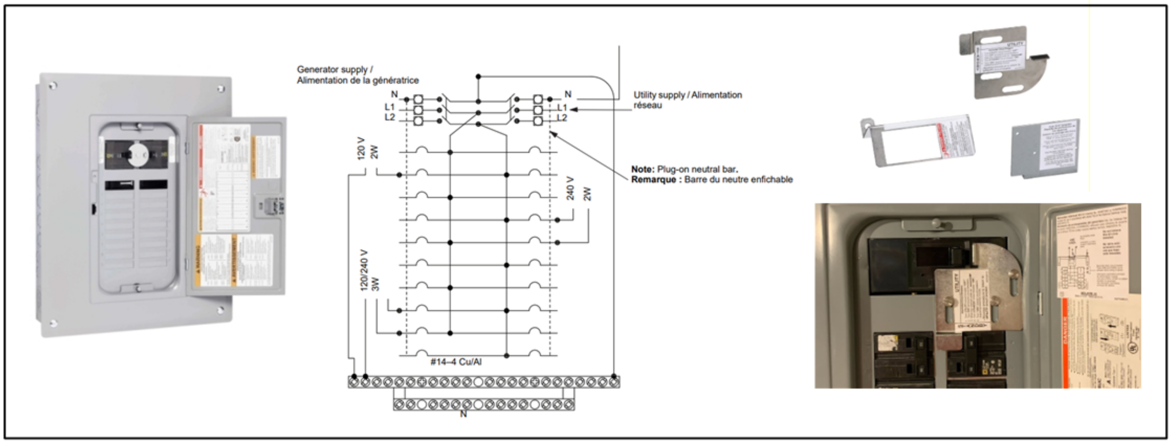
4.7.5 Voltage related reactive power control (volt-var)			
P_{th-vvr}	250	kW	Power thresold for volt-var mode
U_{min2}		per unit	Voltage related reactive power control - Limited operating minimum voltage
U_{min1}		per unit	Voltage related reactive power control - Continuous operating minimum voltage
U_{nom}		per unit	Nominal network Voltage
U_{max1}		per unit	Voltage related reactive power control - Continuous operating maximum voltage
U_{max2}		per unit	Voltage related reactive power control - Limited operating maximum voltage
$Q_{max,overexcited}$		per unit	Voltage related reactive power control - Limited operating maximum power overexcited
$Q_{max,underexcited}$		per unit	Voltage related reactive power control - Limited operating maximum power underexcited
4.7.6 Additional reactive current requirements			
U_c	120	V	Declared system supply voltage
$U_{static-undervoltage}$	0,88	per unit	Lower bondary of the static voltage range
$U_{static-overervoltage}$	1,06	per unit	Higher bondary of the static voltage range
$\Delta U_{Nper-deadband}$	0,00	per unit	Sudden voltage jump deadband
k_1		N/A	Positive sequence current gradient
k_2		N/A	Negative sequence current gradient
N_{per}	60	nb of periods	Number of periods over wich to calculate the average positive and negative sequence voltages
N_{min}	1	min	Duration time over wich to calculate the pre-fault positive and negative sequence voltages
$T_{rc-step}$	25	ms	Reactive current step response time
T_{rc-set}	50	ms	Reactive current settling time
4.7.6 Optional modes			
$Watt_{priotity}$	no	yes/no	Active power priority
$I_{Q-limitation}$	1	per unit	Reactive current limitation
$I_{zero-limitation-enable}$	no	yes/no	Zero current threshold enabled
$U_{zero-limitation}$		per unit	Zero current threshold voltage
$I_{zero-limitation}$	0,05	per unit	Zero current limit
4.9.3 Means to detect islanding situation			
T_{id}	2	s	Unintended island detection time
4.10 Connection and starting to generate electrical power			
$T_{connect}$	300	s	Reconnection time after a disturbance
4.11 Ceasing and reduction of active power on set point			
P_{th-dis}	250	kW	Power threshold for disconnection
4.12.2 Monitoring and control			
P_{th-inf}	250	kW	Power threshold for information exchange

Appendix I

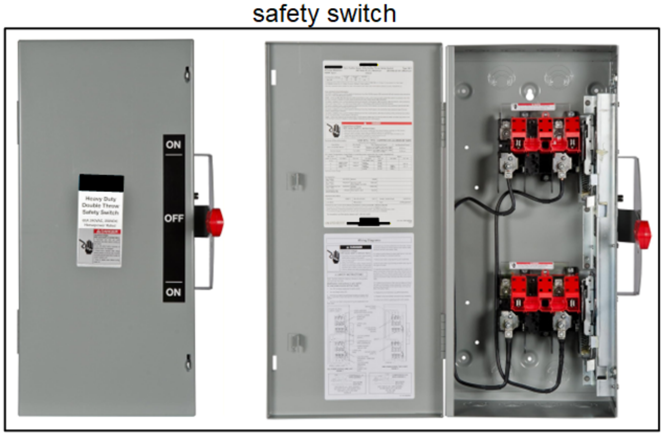
(for information purposes)

Examples of switching devices equipped with a mechanical interlock system

(a) Device equipped with a mechanical interlock system



(b) CSA C22.2 No. 4 or UL 98 certified double throw safety switch



(c) CSA C22.2 No. 178.1 or UL 1008 certified manual transfer switch

(d) CSA C22.2 No. 178.1 or UL 1008 certified automatic transfer switch