How to meet EN50438-IE with non-certified solar PV products in Ireland

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Domestic solar photovoltaic (PV) is not widely installed in Ireland. One reason is that Irish standards and regulations for attaching solar PV products are counterproductive. Adoption by ESB Networks of a solar PV standard that is only used in the small Irish economy has forcibly prevented Ireland from taking advantage of the economies of scale of a major economy. This is highly regressive. The domestic consumer is somewhat boxed in, see: https://www.cs.tcd.ie/coghlan/Elios4you/Domestic-SolarPV-in-Ireland-issues-vision-targets.pdf and other related documents at: https://www.cs.tcd.ie/coghlan/currwork2.htm

For Irish domestic solar PV, ESB Networks require independent certification of solar PV products to EN50438-IE, which excludes self-certified and non-certified products. Further constraints are that SEAI Grant criteria effectively mandate that installations with batteries must be greater than 2kWp, while national planning regulations require planning permission for installations greater than 2kWp (which soaks up any battery grant). The combination of these restrictions leaves few options:

Optimal Installation	Solar PV Products	Certified?	Comments
2kWp + DC-battery-ready hybrid (inverter already certified), no battery	Solis or SolarEdge DC-battery hybrids, no DC battery	Yes	Avoids planning permission and allows adding battery later
3kWp with planning permission, with or without battery	Solis or SolarEdge DC-battery hybrids, w/wo DC battery	Yes	Costs extra for planning permission
	Other non-certified DC-battery hybrids, + Ziehl UFR1001E, w/wo DC battery	No	Costs extra for planning permission and Ziehl UFR1001E
	Other non-certified non-hybrid inverters, + Ziehl UFR1001E, w/wo AC battery [e.g. Victron]	No	Costs extra for planning permission and Ziehl UFR1001E

So for solar PV, the use of a Ziehl UFR1001E at the Grid connection is necessary in order to expand the options. However, this is a comprehensive device that is not simple to install and program (but once understood is simple to handle), and for which "Irish settings" are not provided, and indeed are not trivial to determine.

This document is intended to establish the "Irish settings" for the Ziehl UFR1001E and to outline installation details, and thereby help installers and customers.

1. ESB Networks solar PV microgeneration requirements

The latest (2018) ESB Networks requirements are at: https://www.esbnetworks.ie/docs/default-source/publications/conditions-governing-connection-and-operation-of-micro-generation-policy.pdf?sfvrsn=ad5c33f0_8

The specified national deviations of 2018 and 2009 are different, see Figs.1 & 2 below. The other important provisions that affect settings are given in Sections 3.3.7, 6.2 and 6.3, but these have not changed between 2009 and 2018, see the provisions in Figs.3 & 4 below.

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2.2 National Deviations

Table 1 below displays the specific Irish Settings as published in EN 50438

Parameter	Trip setting	Clearance time
Over voltage	230 V + 10 %	0,5 s
Under voltage	230 V – 10 %	0,5 s
Over frequency	50 Hz + 1 %	0,5 s
Under frequency	50 Hz - 4 %	0,5 s
An explicit Loss of Mains functionality must be included. Established methods such as, but not limited to, Rate of Change of Frequency, Vector Shift or Source Impedance Measurement may be used. Where Source Impedance is measured, this must be achieved by purely passive means. Any implementation which involves the injection of pulses onto the DSO network, shall not be permitted.		
ROCOF [where used]	0,4 Hz/s	0,5 s
Vector Shift [where used]	6 degrees	0,5 s

Table 1: Micro-generation Interface settings for Republic of Ireland

Figure 1: National Deviations of Mar-2009

2.2 *National Deviations*

Table 1 below displays the specific Irish Settings as published in EN 50438

Parameter	Trip setting	Clearance time
Over voltage	230 V + 10 %	0,5 s
Under voltage	230 V – 10 %	0,5 s
Over frequency	52 Hz	0,5 s
Under frequency	47Hz	20 s
An explicit Loss of Mains functionality must be included. Established methods such as, but not limited to, Rate of Change of Frequency, Vector Shift or Source Impedance Measurement may be used. Where Source Impedance is measured, this must be achieved by purely passive means. Any implementation which involves the injection of pulses onto the DSO network, shall not be permitted.		
ROCOF [where used]	1.0 Hz/s	0,6 s
Vector Shift [where used]	6 degrees	0,5 s

Table 1: Micro-generation Interface settings for Republic of Ireland All type

Figure 2: National Deviations of Oct-2018

<u>These changes must be highlighted</u>, as the 2009 settings have been widely disseminated, and may give rise to confusion over why some “Irish settings” no longer conform.

6.2 *Under-Over voltage*

The operation of the micro-generator under/over voltage protection can be verified either under normal operating conditions (i.e. tripping the generator) or independently of the generator if suitable test attachments are provided. Operation of the under/over voltage protection will be demonstrated for each of the voltage ranges defined in Section 2.2. For each trip setting (upper and lower) the operation of the protection within the specified clearance time shall be demonstrated for an increase or decrease of voltage within 2.3 V around the trip setting. In either case it will be necessary to verify that a protection operation will cease energize the ESB network The test voltages shall be 230 V plus and minus n times 1 % of the nominal voltage for a duration that is longer than the trip time delay, for example 2 s in the case of a delay setting of 1.5 s. It will be necessary to carry out five tests for each trip setting, the longest trip time is to be recorded as the certificated trip time.

6.3 *Under-Over frequency*

The operation of the micro-generator under/over frequency protection can be verified either under normal operating conditions (i.e. tripping the generator) or independently of the generator if suitable test attachments are provided. In either case it will be necessary to verify that a protection operation will cease energize the ESB network. Operation of the under/over frequency protection will be

demonstrated for an increase or decrease of frequency within ± 0,5 % of the trip settings (e.g. for an over frequency setting of 50,5 Hz the permissible operating range is (50.5 ± 0.2525) Hz. The test frequency shall be applied in steps of 0,5 % of setting for a duration that is longer than the clearance time delay, for example 1 s in the case of a delay setting of 0,5 s. For both the upper and lower limits, the time to trip from the point at which the frequency reaches the limit will be recorded for five separate tests and the longest trip time recorded as the declared trip time.
It should not be necessary to disable LoM protection as the approach rates are deliberately specified to be less than the LoM trip settings.
The highest deviations from the frequency settings are to be recorded as the certificated trip settings.

Figure 3: Test conditions of Oct-2018

*NB1: After each test, UFR1001E counts down **doF**, so for faster testing of limits several times as above, set **doF** = 0*
*NB2: **doFA** can simultaneously set the **doF** of all alarms, see UFR1001E operating manual, page 23*

3.3.7 Automatic reconnection after a network outage

The interface protection shall ensure that feeding power to the ESB's network will only commence, after the voltage and frequency on the ESB's network, have been within the limits of the interface protection settings for a minimum of

- 3 min for mechanical ac generation;
- 20 s for inverter based systems.

In order to facilitate such automatic reconnection power input to the interface protection equipment and sensing connections to the interface protection shall be made on the ESB Networks side of the disconnector (but on the micro-generator
side of the isolator) that is initiated by the interface micro-generator protection.
Manufacturers should give consideration to limiting the number of attempted reconnections within any one period of time.

Figure 4: Automatic Reconnection of Oct-2018

Hence the aggregated changes are:

Setting	2009	2018
Overfrequency trip	50.5 Hz	52 Hz
Underfrequency trip	48 Hz	47 Hz
Underfrequency delay	0.5 sec	20 sec
ROCOF trip	0.4 Hz/s	1.0 Hz/s
ROCOF delay	0.5 sec	0.6 sec

The Ziehl UFR1001E datasheet, quick guide and manual use many unfamiliar terms:

Major	**Minor**	**Meaning**
U¯ ¯	**U¯ ¯**	Extreme overvoltage settings
	U¯ ¯Alarm on/off	Alarm enable/disable; but sometimes settings are preset that may or may not be required, depending on application; so to enable any trip settings defined, set Alarm=ON
	U¯ ¯Overvoltage	Trip voltage (1V resolution)
	H¯ ¯Hysteresis	Recovery occurs **doF** after (**U¯ ¯- H¯ ¯**) volts
	dAL Response time	Time before trip occurs
	doF OFF-delay	Delay after the recovery limit is reached until actual recovery occurs; **doF** **<u>MUST</u>** be set, it cannot be undefined
U¯	Similar to above	Nominal overvoltage settings; for hysteresis, recovery occurs **doF** after (**U¯ - H¯**) volts
U∩	Similar to above	10 minute average overvoltage settings, where for hysteresis, recovery occurs **doF** after (**U∩ - H∩**) volts
U_	Similar to above	Nominal undervoltage settings; for hysteresis, recovery occurs **doF** after (**U_ + H_**) volts
U_ _	Similar to above	Extreme undervoltage settings; for hysteresis, recovery occurs **doF** after (**U_ _+ H_ _**) volts
F¯ ¯	Similar to above	Extreme overfrequency settings; for hysteresis, recovery occurs **doF** after (**F¯ ¯- H¯ ¯**) Hz
F¯	Similar to above	Nominal overfrequency settings; for hysteresis, recovery occurs **doF** after (**F¯ - H¯**) Hz
F_	Similar to above	Nominal underfrequency settings; for hysteresis, recovery occurs **doF** after (**F_ + H_**) Hz
F_ _	Similar to above	Extreme underfrequency settings; for hysteresis, recovery occurs **doF** after (**F_ _ + H_ _**) Hz

NB: Ziehl UFR1001E voltage settings resolution is 1V, so can only be set in steps of 1V, but hysteresis resolution is 0.1V.

There are several important policies that must be established:

(1) As can be seen, the Ziehl UFR1001E supports “extreme” or “fast” voltage and frequency trip settings, for which faster trip delays are usual. ESB Networks does not define "extreme" settings, but some solar PV device manufacturers that operate in the Irish market do so (e.g. Enphase), and since Ziehl support these useful settings it is suggested to use them. It is suggested “extreme” voltage be defined symmetrically as 50% beyond nominal trip voltage (as per Enphase), and “extreme” frequency be defined symmetrically as 50% beyond nominal trip frequency (Enphase defines asymmetrically), and “extreme” response time be 0.2 seconds for voltage and 0.1 seconds for frequency (as per Enphase). The voltages must be rounded to 1V for the Ziehl UFR1001E.

(2) The Ziehl UFR1001E also supports 10 minute average settings, which ESB Networks does not define. It is suggested the 10 minute average settings be made equal to the nominal overvoltage settings.

(3) Also the Ziehl UFR1001E supports Hysteresis settings, whilst ESB Networks does not define these. However Sections 6.2 and 6.3 specify test ranges for voltage and frequency, see Fig.3. For voltage, tests must be performed over a range of ± 2.3V, i.e. a total range of 4.6V, i.e. 2% of 230V. For frequency, the range is ± 0.5% of the trip setting, i.e. a total range of approx.1% of 50Hz. Thus in %, the voltage range is 2 times the frequency range. It might be expected that ESB Networks have a Grid policy justifying this. Let us assume such a Grid policy exists. Then it is suggested that the 2x balance of these ranges be used for hysteresis too, so that, in %, the voltage hysteresis is 2 times the frequency hysteresis. There remain related issues. For overvoltage the Ziehl UFR1001E recovers after voltage has fallen below (trip - hysteresis) volts, giving two obvious policy choices:

Option	**Trip Voltage**	**Recovery Voltage**	**Hysteresis**
(a)	EN50438-IE limit + hysteresis/2	EN50438-IE limit - hysteresis /2	hysteresis
(b)	EN50438-IE limit	EN50438-IE limit - hysteresis	hysteresis

Hysteresis for undervoltage can be treated similarly but with signs reversed. Over and under frequency can be treated likewise, although tight frequency limits can constrain the frequency hysteresis to be unreasonably tight (which the 2009 limits of Fig.1 exacerbate, whilst the 2018 limits of Fig.2 alleviate). Policy (a) yields trip values that differ from the EN50438-IE limits, and so is less desirable than policy (b), which does conform. The other choice, hysteresis, requires a balance between chatter, see (4) below, and the noise margin between the EN50438-IE limits. The balance needs to be such as to minimize chatter but also allow continued operation when voltage or frequency spends more time in one portion of the margin than in another. It is suggested policy (b) be adopted, with a 2% voltage hysteresis (4.6V, like Enphase) and 1% frequency hysteresis (0.5Hz). This is logical, uniform for upper and lower limits, and in % yields voltage hysteresis 2x frequency hysteresis, and so adheres to whatever Grid policy that ESB Networks use to justify their test ranges. The noise margin is generous and chatter is dealt with below.
ESB Networks is considering the suggested overfrequency hysteresis; it may change!

(4) The Ziehl UFR1001E OFF-delay **MUST** be set, it cannot be undefined. ESB Networks 2018 requirements Sec.3.3.7, page 5 says that an inverter based system should wait 20 seconds before attempting reconnection after a network outage. It is suggested 20 seconds be used as the UFR1001E OFF-delay (reconnection) setting. The Ziehl UFR1001E could invoke repeated trips and reconnects (chatter). The UFR1001E will not be affected by chatter, but connected equipment or the Grid may be. However the choice of reconnect delay time of 20 seconds should eliminate this as the delay will reset itself if the Grid goes out of range again during the countdown. NB: **doFA** can simultaneously set the all the OFF-delays, see the UFR1001E operating manual, page 23.

(5) The ESB Networks 2018 requirements Sec.2.2, Table 1, page 3 says either ROCOFF or vector shift can be used. It is suggested here that ROCOFF be used, in which case the vector shift settings may be left undefined.

(6) It is suggested to start programming in UFR1001E program 20, which is closest to the settings defined in Section 2 below. Also since the **Un** Alarm on/off is OFF for almost all UFR1001E programs, it is suggested to set **Un** Alarm ON before any other programming.

These policies can now be used to construct a table of Ziehl UFR1001E “Irish Settings” to meet EN50438:2013-IE as defined by ESB Networks in Oct-2018, see Section 2 below. Ziehl UFR1001E installation details are then given in Section 3 below.

2. Ziehl UFR1001E "Irish Settings" for EN50438:2013-IE

(to meet EN50438:2013-IE as defined by ESB Networks in Oct-2018)

Menu	**Parameter / Unit**	 **IRELAND EN50438:2013-IE 1AC+N 230V**	**Comments**
U¯ ¯	**U¯ ¯** Alarm on/off	ON	Must be ON to enable settings
	U¯ ¯ Overvoltage	264 V	[extreme] (253-230V) * 50% as per (1) above
	H¯ ¯ Hysteresis	15.6 V	Recovery at 248.4V as per (3) above
	dAL Response time	0.2 sec	As per (1) above
	doF OFF-delay	20 sec	As per (4) above
U¯	**U¯** Alarm on/off	ON	Must be ON to enable settings
	U¯ Overvoltage	253 V	230V + 10% as per Fig.2
	H¯ Hysteresis	4.6 V	Recovery at 248.4V as per (3) above
	dAL Response time	0.5 sec	As per Fig.2
	doF OFF-delay	20 sec	As per (4) above
U∩	**U∩** Alarm on/off	ON	Must be ON to enable settings
	U∩ Overvoltage	253 V	[10min average] As per (2) above
	H∩ Hysteresis	4.6 V	As per (2) above
	dAL Response time	0.5 sec	As per (2) above
	doF OFF-delay	20 sec	As per (2) above
U_	**U_** Alarm on/off	ON	Must be ON to enable settings
	U_ Undervoltage	207V	230V - 10% as per Fig.2
	H_ Hysteresis	4.6 V	Recovery at 211.6V as per (3) above
	dAL Response time	0.5 sec	As per Fig.2
	doF OFF-delay	20 sec	As per (4) above
U_ _	**U_ _** Alarm on/off	ON	Must be ON to enable settings
	U_ _ Undervoltage	196 V	[extreme] (207-230V) * 50% as per (1) above
	H_ _ Hysteresis	15.6 V	Recovery at 211.6V as per (3) above
	dAL Response time	0.2 sec	As per (1) above
	doF OFF-delay	20 sec	As per (4) above
F¯ ¯	**F¯ ¯** Alarm on/off	ON	Must be ON to enable settings
	F¯ ¯ Overfrequency	53 Hz	[extreme] (52-50Hz) * 50% as per (1) above
	H¯ ¯ Hysteresis	1.5 Hz	Recovery at 51.5Hz as per (3) above
	dAL Response time	0.1 sec	As per (1) above
	doF OFF-delay	20 sec	As per (4) above
F¯	**F¯** Alarm on/off	ON	Must be ON to enable settings
	F¯ Overfrequency	52 Hz	50Hz + 4% as per Fig.2
	H¯ Hysteresis	0.5 Hz	Recovery at 51.5Hz as per (3) above
	dAL Response time	0.5 sec	As per Fig.2
	doF OFF-delay	20 sec	As per (4) above
F_	**F_** Alarm on/off	ON	Must be ON to enable settings
	F_ Underfrequency	47 Hz	50Hz - 6% as per Fig.2
	H_ Hysteresis	0.5 Hz	Recovery at 47.5Hz as per (3) above
	dAL Response time	20 sec	As per Fig.2
	doF OFF-delay	20 sec	As per (4) above

F_ _	**F_ _** Alarm on/off	ON	Must be ON to enable settings
	F_ _ Underfrequency	45.5 Hz	[extreme] (47-50Hz) * 50% as per (1) above
	H_ _ Hysteresis	2.0 Hz	Recovery at 47.5Hz as per (3) above
	dAL Response time	0.1 sec	As per (1) above
	doF OFF-delay	20 sec	As per (4) above
UonF	**UonF** on/off		
	UonF voltage		
uSr	**uSr** Alarm on/off		
	uSr Vector shift		
	doF OFF delay		
	dEon suppression time		
	uSr number of phases		
rocF	**rocF** Alarm on/off	ON	Must be ON to enable settings
	dFft delta f / delta t	1.0	As per Fig.2
	Per periods	10	Per = 10 (200ms) + dAL = 0.4sec → response time 0.6sec
	dAL response time	0.4	See for Per above, to give response time as per Fig.2
	doF OFF-delay	20	As per (4) above
rEL	**trEL** response time Y x		
	doFA mode		
	doFA response time all		
ddı	**ddı** display delay		
	dı t display duration **SCn**		
Sı	**U** nominal voltage		
	F nominal frequency		
	uSr nominal Vector shift		
CodE	**Pin** PIN code		
	CodE on/off		
InFo	**Fnr** firmware version		
	Snr serial number		
	H operating hours		
	Err error count		
	Pr program		

3. Ziehl UFR1001E installation details

Another important concern in the connection to the Grid is the other hardware that is needed. The Ziehl UFR1001E decides when the system should be connected or disconnected but some contactors are needed to do the physical actions.

Figs.5 and 6 show an example for use with a Victron MultiPlus II 3kVA inverter. There are two normally open mechanical contactors (in this case they are 40A with 230VAC coils). The reason for two is for redundancy in case one of the contactors fails. There is also a 2A MCB to protect the contactor coils. Fig.7 shows the associated schematic with a Victron ET112 power meter. There is a fuse shown on the neutral feeding the power meter. This fuse value is 375mA but it is not shown. The contactors need to be sized to suit the inverter and the cables for different situations. A wired seal with a serial number should be used to seal the lock button on the Ziehl UFR1001E after the system has been commissioned, as shown in Fig.5.

Figure 5: Victron Anti-Islanding Box using Ziehl UFR1001E

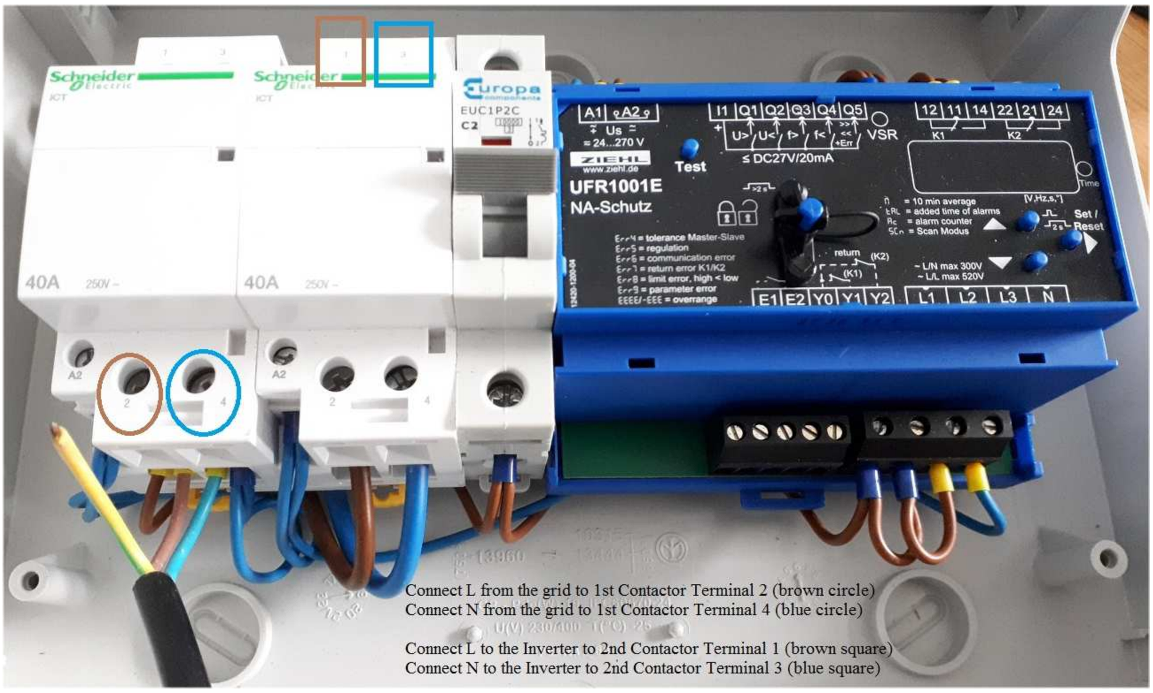
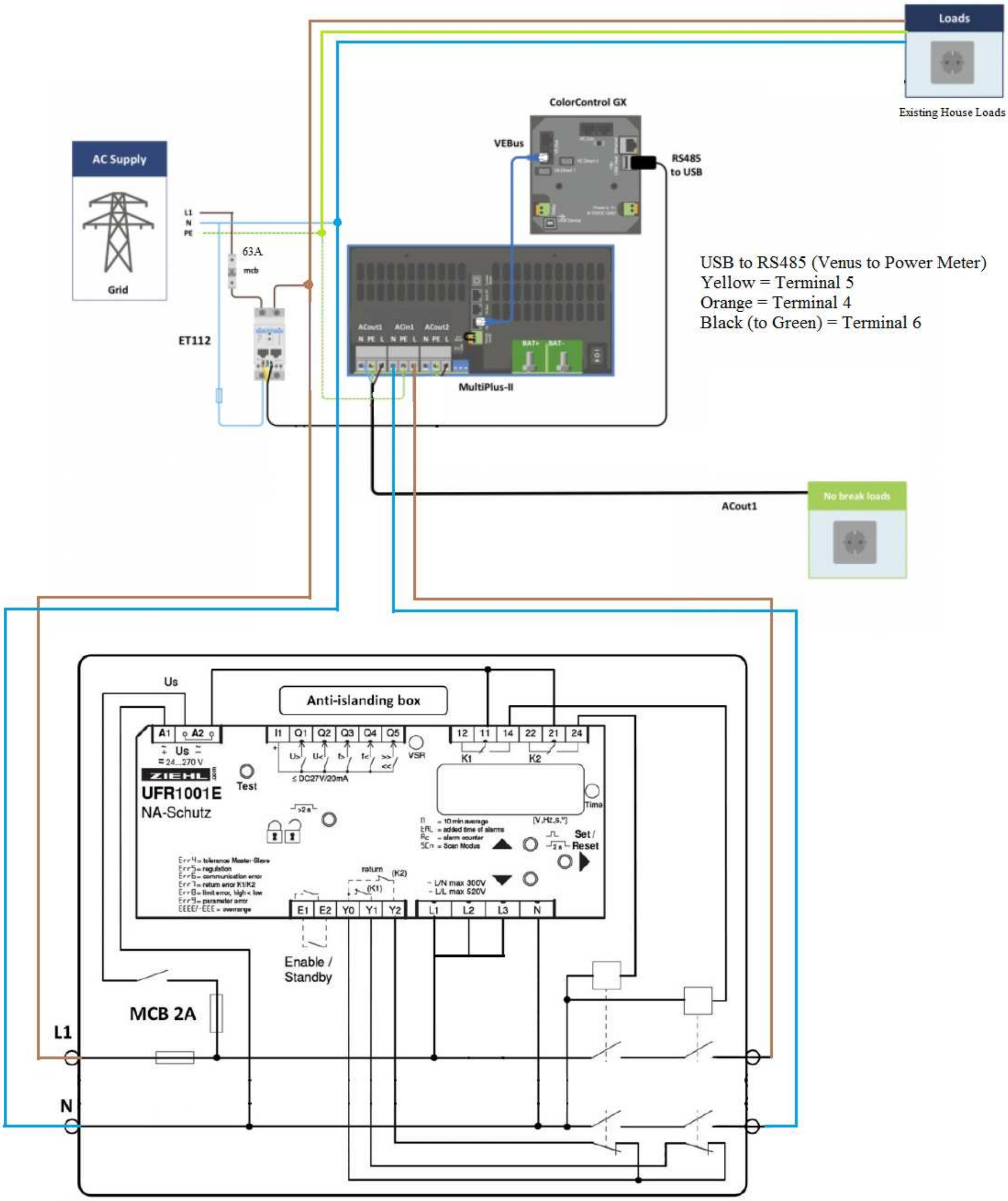


Figure 6: Victron Anti-Islanding Box internal view showing connections



Power Meter ET112 is installed after the main 63A consumer unit fuse. The power meter measures all current flowing in/out of the consumer unit.
The power meter needs to be connected to the Venus GX. This can be achieved by direct cable

The existing house wiring is left untouched.
The Anti-Islanding box is to be located before AC-In of the MultiPlus inverter. The purpose of the Anti-Islanding device is to disconnect the inverter from the mains and to meet EN50438-2013 regulations for grid connection.
The critical loads are connected to AC-Out1. The loads on this output should not be connected to the grid, they should be a stand alone circuit only fed by the inverter.

Figure 7: Victron Anti-Islanding Box wiring when used with Victron Multiplus II
ESB Networks is considering the need for double contactors; it may change!