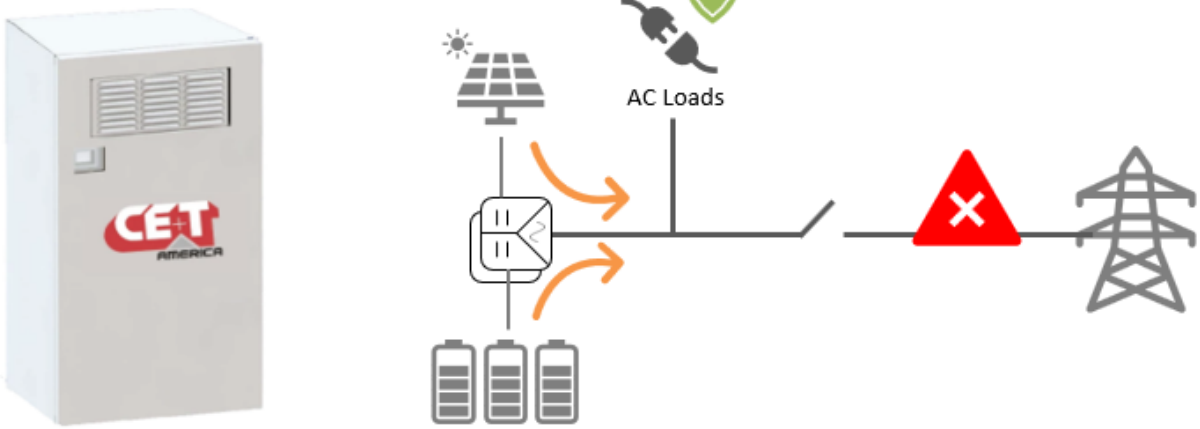
Leading Conversion and Storage Technology for Energy Saving and Power Resilience

Stabiliti™ – Islanding Switchgear Guide



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1. About This Document

This document is CE+T America proprietary. It is a customer facing document aimed to serve as an operational guide for Islanding Switchgear which is used to support Stabiliti converter's microgrid operation.

Document Revision History:

Date	Revision	Notes
Oct 25th, 2021	A	Initial draft
March 17th, 2022	B	Renamed Single wire method to avoid confusions.

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2. Glossary of Terms

Acronym of Term	Full Expression
AWG	American wire gauge
CEC	California Energy Commission
GFDI	Ground fault detection current
IMI	Isolation monitor interrupter
BESS	Battery energy storage system, specifically e-ON's. Based on context in the manual, BESS may refer to complete system including eON batteries and PCS.
PCS	Power conversion system, specially Stabiliti 30C3
PV	Photovoltaic
LCD	Liquid Crystal Display
RSS	Rapid shutdown system
RSE	Rapid shutdown equipment
BoS	Balance of system components
BAMS	Battery array management system
MBMS	Master battery management system
CAN	Communication protocol
Modbus	Communication protocol
SoC	State of charge of batteries, specified in percentage.
UPS	Uninterrupted power supply
HMI	Human machine interface, touch screen or web interface
PPE	Personal Protective Equipment
CCS	Customer Control System
GIC	Grid interconnect contactor
SEL	Schweitzer Engineering Laboratories

3. Important Safety Instructions

The following safety symbols are used in this manual:

Danger – Procedure or situations that require action to prevent personal injury/death or damage to equipment/environment.

Warning – Indicates a potentially hazardous situation that, if not avoided, can result in serious injury or death.

Important Information: Includes key information for the operation of this equipment or specific instructions to maintain the warranty.

Personal Protective Equipment: This symbol means that use of personal protective equipment is highly recommended. This includes insulated gloves, steel toed boots, hard hat, reflective fire-resistant vests, and protective eye goggles.

Note that the equipment must be handled, installed, and operated by qualified engineer/technician with proper training on handling high/medium voltage electrical equipment. Local and national electrical code must be used during installation and operations. Failure to observe safety standards could result in personal injury or damage to equipment/environment.

Danger - All instructions regarding the configuration of this device must be followed. Failure to follow may result in injury, death, or damage to equipment.

Danger - To avoid an electric shock, verify that the Converter's external AC and DC Disconnects are open (off). A minimum wait time of five (5) minutes is required after opening AC and DC Disconnects to assure that the Converter's internal capacitors have discharged to zero voltage before performing any work on the Converter. Utilize lockout procedures to ensure that both AC and DC Disconnects remain in the off position during all service periods.

Danger – The enclosure contains exposed high voltage conductors. The enclosure front access door must remain closed, except during installation, commissioning, or maintenance by trained service personnel. Do not remove the front doors if extreme moisture is present (rain, snow, or heavy dew).

Danger – To avoid an electric shock, verify that the Converter's external AC and DC Disconnects are open (off). A minimum wait time of five (5) minutes is required after opening AC and DC Disconnects to assure that the Converter's internal capacitors have discharged to zero voltage before performing any work on the Converter. Utilize lockout procedures to ensure that both AC and DC Disconnects remain in the off position during all service periods.

Warning – These instructions DO NOT contain any information on the operation of battery systems outside of this product. Refer the manufacturer for the battery system for installation and servicing instructions.

Danger – Ensure that the equipment is adequately installed and grounded per NFPA and all applicable NEC codes.

Danger – Do not leave foreign objects in the enclosure. Keep the area around the enclosure clear of trash, debris, and other combustible materials.

Warning – Personnel Qualification: Inspections and operations requiring access to lethal AC or DC voltages, should only be performed by qualified personnel.

Warning – All field wiring must conform to the codes set forth in the National Electric Code ANSI/NFPA 70.

Warning –Replace damaged warning and precautionary labels.

Refer to “Reference Documents” section of this manual for details on manuals/documents that should be read first before proceeding.

4. Overview

This document serves as a guide to Islanding Switchgear which supports Stabiliti 's microgrid operation. There are different ways Stabiliti's can be commanded to form grid (i.e., microgrid operation) and using Islanding Switchgear is one of them. This document will go over field connections and operations overview of Stabiliti's microgrid operation using Islanding Switchgear. Refer to applicable detailed app notes for further details.

5. System Rating

Note that the max number of Stabiliti that can be used to form microgrid is 8 (240 kw total as one Stabiliti is 30 kw). There is no minimum limit though. Microgrid function can be achieved via a single Stabiliti as well. Islanding Switchgear can support anywhere from 1 to 8 Stabiliti (loads must be on 480 volt side). Note that there are two versions of Islanding switchgear, one for US and one for Europe.

6. Reference Document

6.1. MAN - 00115 – Stabiliti Series 30 KW – Installation and Operation Manual – V1.0

6.2. MAN - 00114 – Stabiliti Series 30 KW – Quick Start Guide – V1.0

6.3. Stabiliti - Microgrid Guide - Rev 1

6.4. DOC – 000xx – App Note – Customer Controlled Microgrid Guide

6.5. DOC – 503 – App Note – Rapid Backup Power Solution Guide

6.6. DOC - 00033 – App Note – Transformer & Interconnection

7. Microgrid Operation – Synchronous Vs Asynchronous

In essence, microgrid operation means that the Stabiliti will form grid and keep the loads running even when the grid is lost. For Stabiliti to be able to do so, there are specific software settings and specific ways to set the whole system up from wiring standpoint. The exact settings depend on desired microgrid operation. Before we go into further details, it's important to understand the difference between synchronous and asynchronous microgrid function.

Synchronous means that upon receipt of appropriate commands (and grid conditions), ALL Stabiliti s in the system will start forming (or following) the grid at the exact same time. Such operation is required when the load that needs to be powered up is exactly equal to the size of Stabiliti installation. To achieve this, a use of islanding switchgear or following "customer controlled microgrid" method is crucial. This of course adds cost and adds some complexity to the overall control.

If the load that is supposed to be protected is controllable, meaning it can be gradually brought online then an asynchronous way of controlling microgrid is a cheaper alternative. In asynchronous mode, individual Stabiliti are brought online one by one. They may all receive "microgrid command" at the same

time but there might be a slight delay for individual units to start forming microgrid. Due to this limitation, this method is ideally suited for completely off grid applications.

Islanding Switchgear supports full synchronous microgrid operation.

8. Microgrid Operation Overview

There are three different ways of achieving microgrid operation. Each one has their own pros and cons. Note that there is a max limit of 8 converters while forming microgrid. Refer to the table below for details:

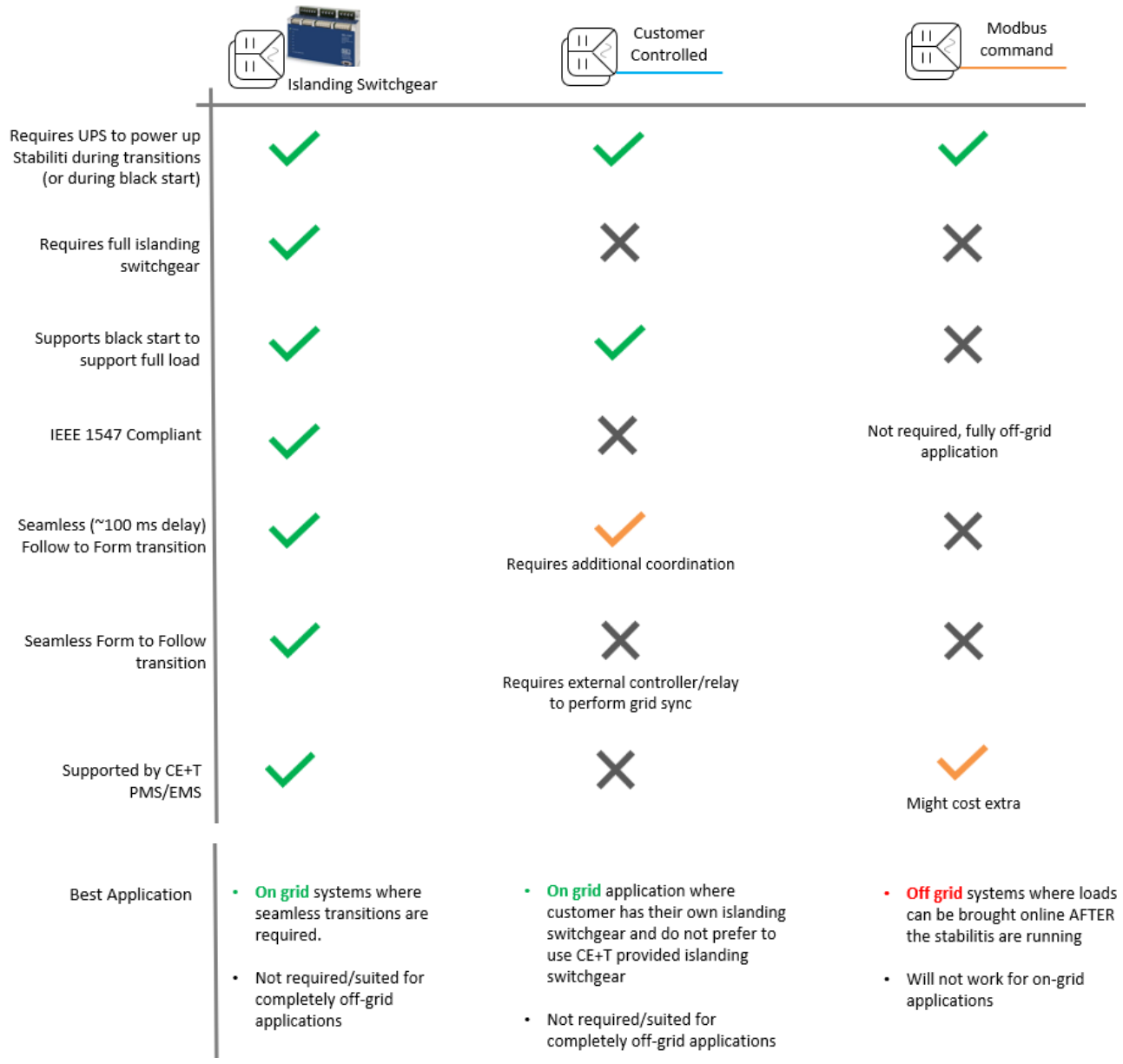


Figure 1 - Microgrid Operation - Three Ways

Refer to the section below to gain better understanding of each term used in the table above.

Definitions:

- On grid means system is normally connected to grid. But when grid is lost, the Stabiliti system is required to form microgrid to support the loads.
- Off grid means the system has no connection to the grid at all and there will never be an actual grid connection.
- Black start refers to a mode of operation where the load is required to be brought online from a completely offline state.

Here is a summary of pros and cons of all three methods:

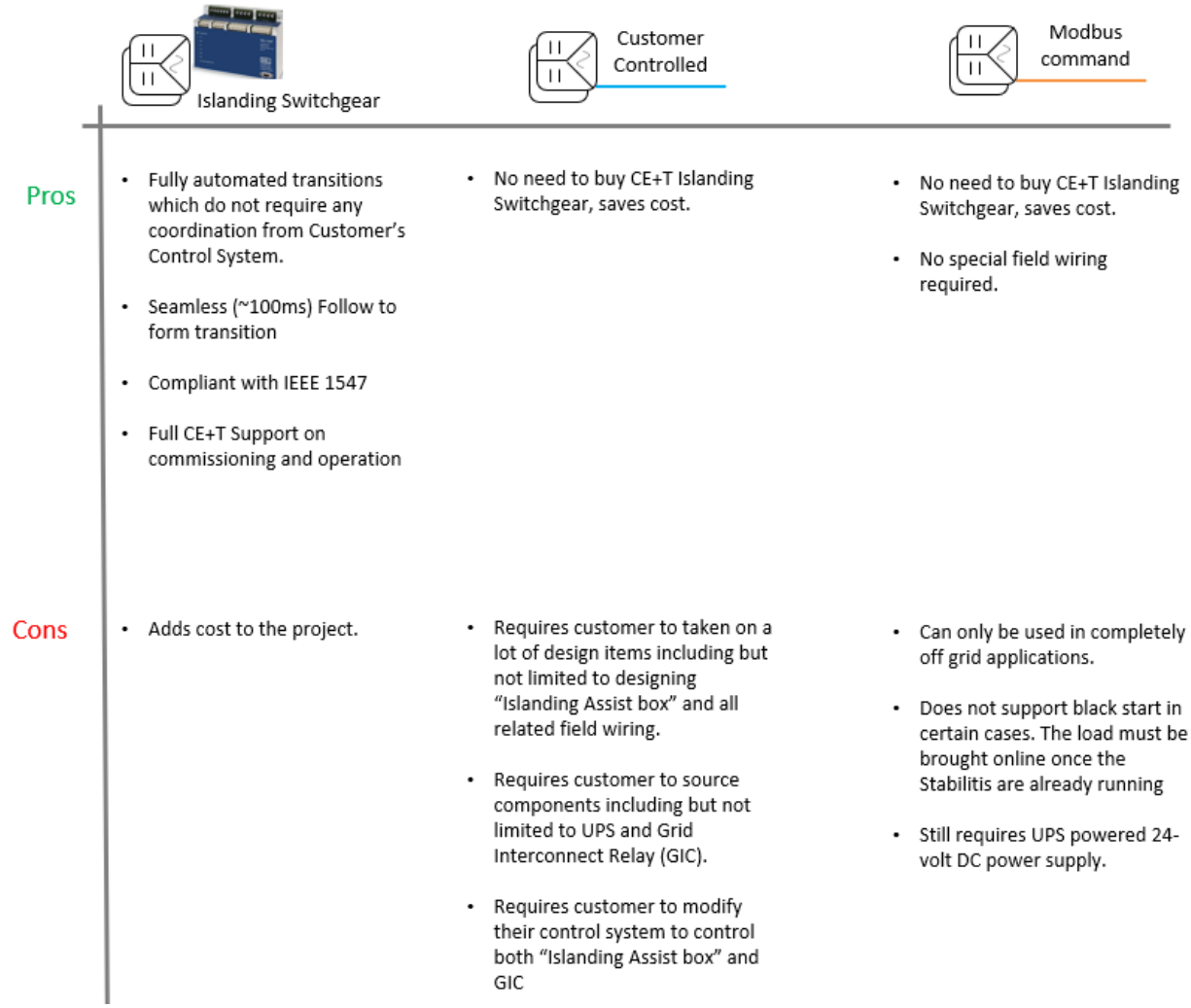


Figure 2 - Pros and Cons of Different Microgrid Operation Methods

9. Microgrid Operation Overview – Islanding Switchgear Method

This is how the system shall be interconnected when using CE+ T supplied islanding switchgear:

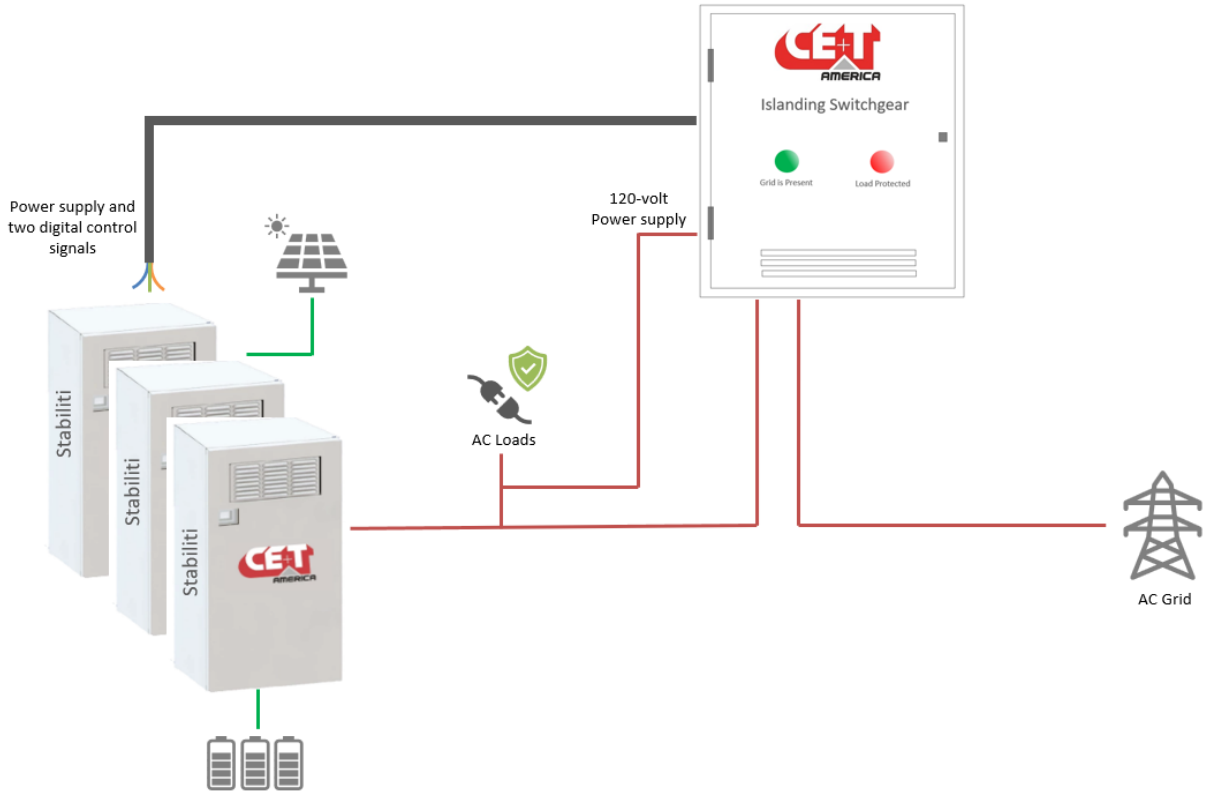


Figure 3 - Microgrid Operation – Islanding Switchgear Method

9.1. Field Wiring:

The AC connection from Stabiliti will go into an AC distribution panel (not shown above) and then into "Islanding Switchgear". From there, it will connect to the grid. Note that the "power supply and digital control signals will go from "Islanding switchgear" to one Stabiliti and then connection to subsequent Stabiliti will be daisy chained from this Stabiliti. Note that the "Islanding Switchgear" design may look different (look and feel) than the one shown in figure above. The field connections and functionality will remain the same. This is the most recommended mode of operation for all "on grid" applications.

9.2. System Startup – Initial Start of System:

The system must be set up when the grid is present. Upon interconnecting everything, the SEL relay will engage 24 volts to the two digital signals connected to Stabiliti and at the same time it will energize/close the Grid Interconnect Contactor (GIC). At this time the load is powered via the grid. Now each stabiliti should be manually commissioned and brought online. Note that Stabiliti's AC port must be set in "FPWR" mode. When grid is present and SEL relay is not commanding the Stabiliti to form the grid, Stabiliti will wait for a Customer Control System (CCS) to send a power command to support the load.

9.3. Follow to Form Operation – Loss of Grid:

When the grid is lost, the SEL relay detects the loss of grid and notifies the Stabiliti to start getting ready to form the microgrid. After this, SEL relay opens the GIC. Upon successful GIC operation, SEL reports back to Stabiliti that its ok to form microgrid now. This whole process takes around 100 ms. Note that once Stabiliti are forming the grid, they will ignore power command sent by CCS and will keep the loads on by appropriately taking power from the two DC ports.

The Stabiliti's on board control systems are normally powered via the 480-vac connection. During the "following to forming" transition, the UPS within the Islanding switchgear provides power to keep the internal Stabiliti controls running.

9.4. Form to Follow Operation – Grid is Back:

When the grid is back, SEL ensures that the grid formed by Stabiliti is in sync (phase, voltage, frequency) with the grid and upon successful sync, SEL relay closes the GIC and releases both microgrid command signals from Stabiliti. This transition is almost seamless.

9.5. Application:

Using this method adds cost to the system but it greatly automates the microgrid function. A customer control system will have to make no decision to enable any of "forming to follow" or "follow to forming" transitions. This is best suited for all "on grid" applications.

9.6. Design Consideration:

Read through this full document and all applicable application notes, system manual, BESS manual etc before proceeding. Note that for stabiliti to be able to reliably support microgrid, a stable source of power, like batteries must be connected. Batteries can be paired with PV (on the second DC port). Also note that load must be less than combined power output of the entire system. For instance, if the loads that needs to be backed up is 90 kw, its advisable to use 4 instead of 3 Stabiliti.

10. Field Wiring – Power Supply

Islanding Switchgear has a UPS within it that requires to be powered via a standard outlet (120 volt for US version and 230 volts for EU version). A standard three prong cable must be connected to "VAC in" terminal block for the supply power.

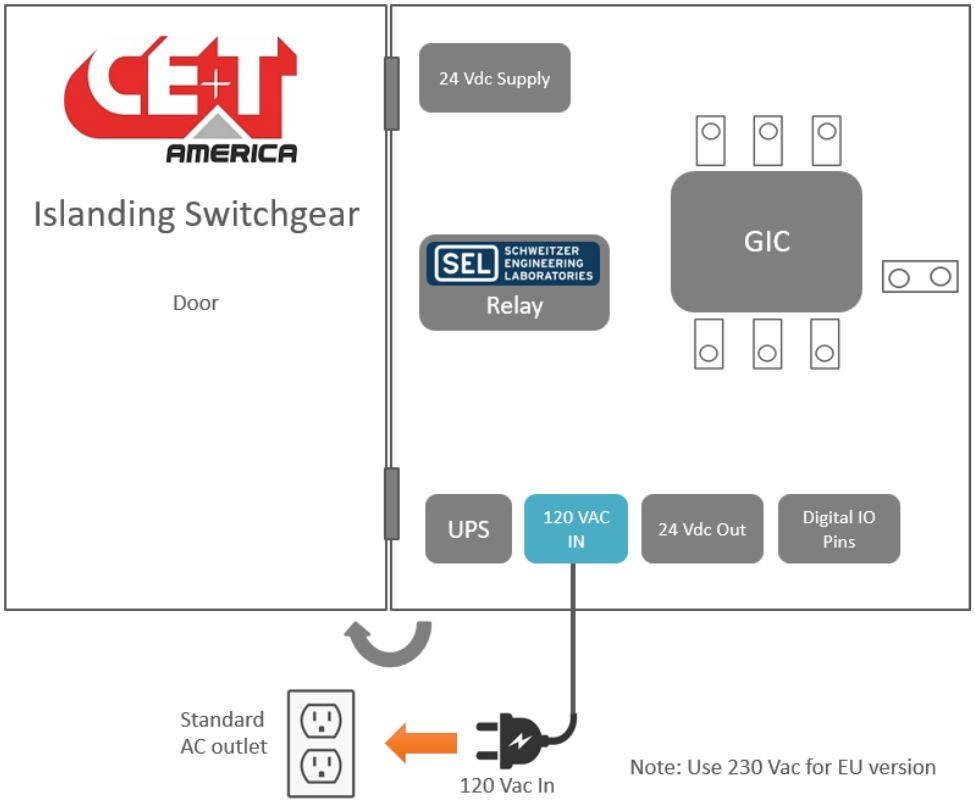
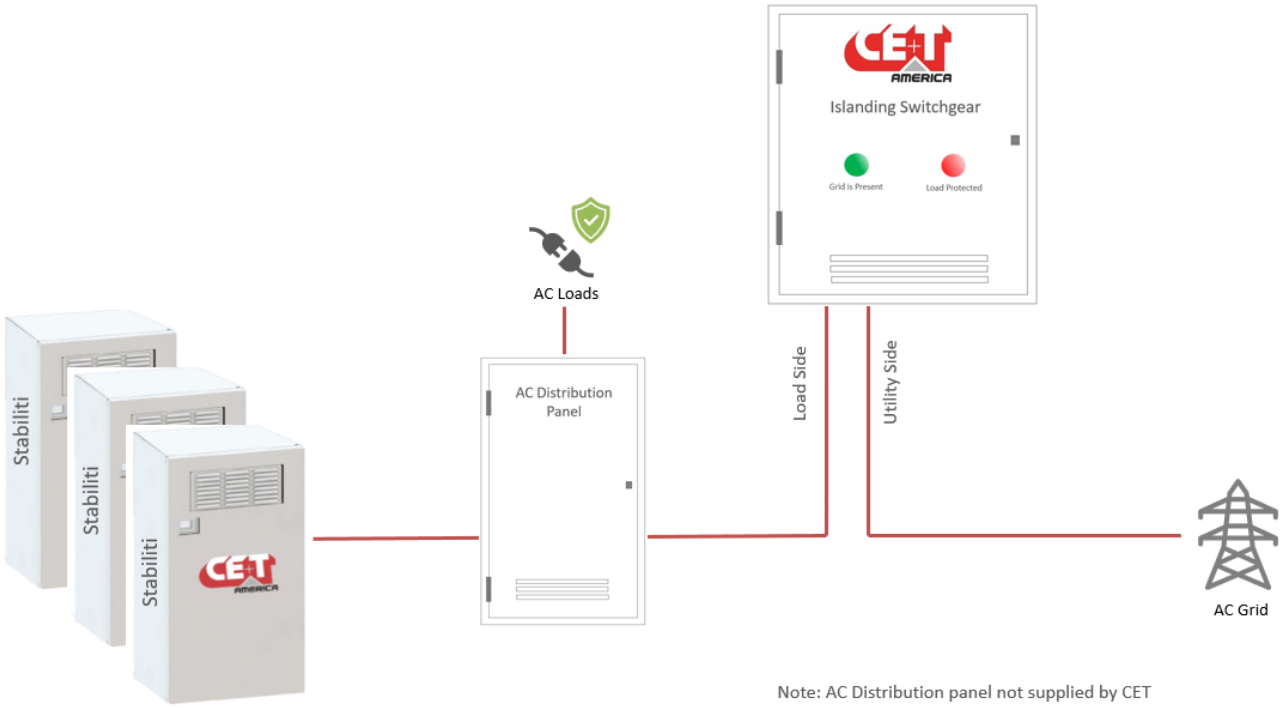


Figure 4 - Field Wiring – Islanding Switchgear Supply Power

11. Field Wiring – Utility and Load

During the time microgrid is active, the Stabiliti and loads must be isolated from the utility tie in connection. To enable that, there is a “grid interconnect contactor” (GIC) within the Islanding Switchgear solely controlled by the SEL relay (which is also within the Islanding Switchgear). Note that no coordination from a site controller or a PMS is required for operation of SEL or the GIC. The utility and combined load connections must be wired to the GIC as shown below:



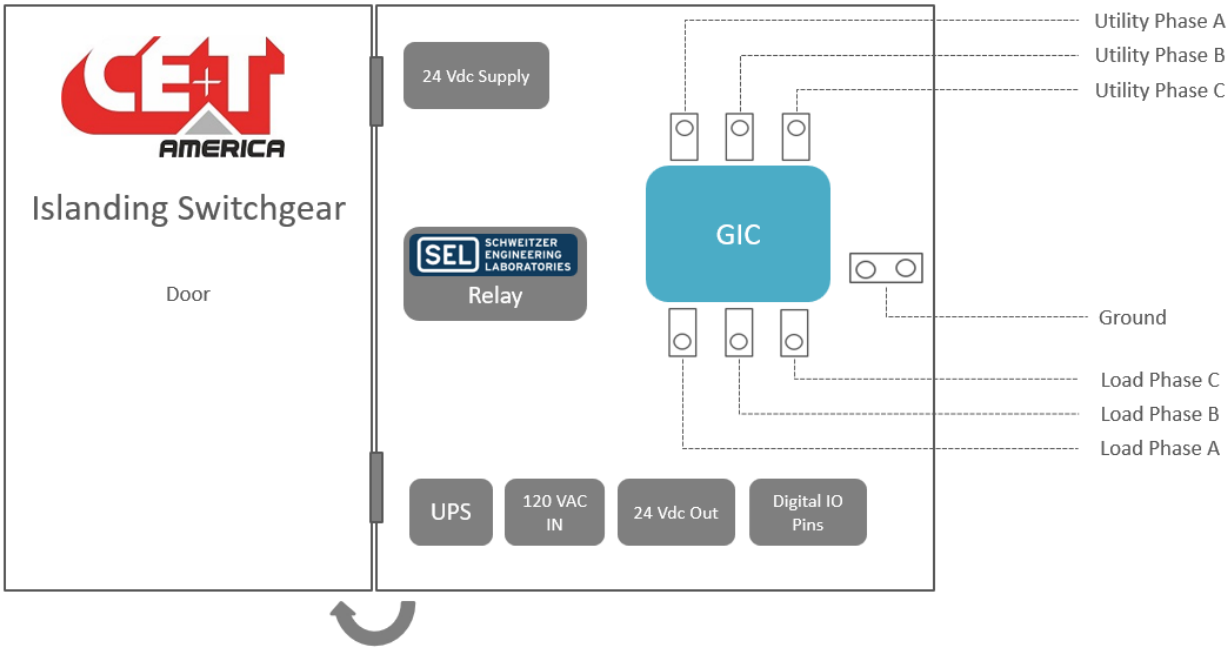


Figure 5 - Field Wiring - Utility and Load Side

12. Field Wiring – Stabiliti Supply Power

There are two ways to power Stabiliti's control board. Through 480 VAC or using an external 24 Vdc power supply. During microgrid operation, there is no 480 Vac supplied by Utility. So, to keep Stabiliti powered through the "following to forming" transition, an external power supply source must be used. Islanding Switchgear houses a UPS supported 24 Vdc power supply for the very same reason. Wiring is straight forward as shown below:

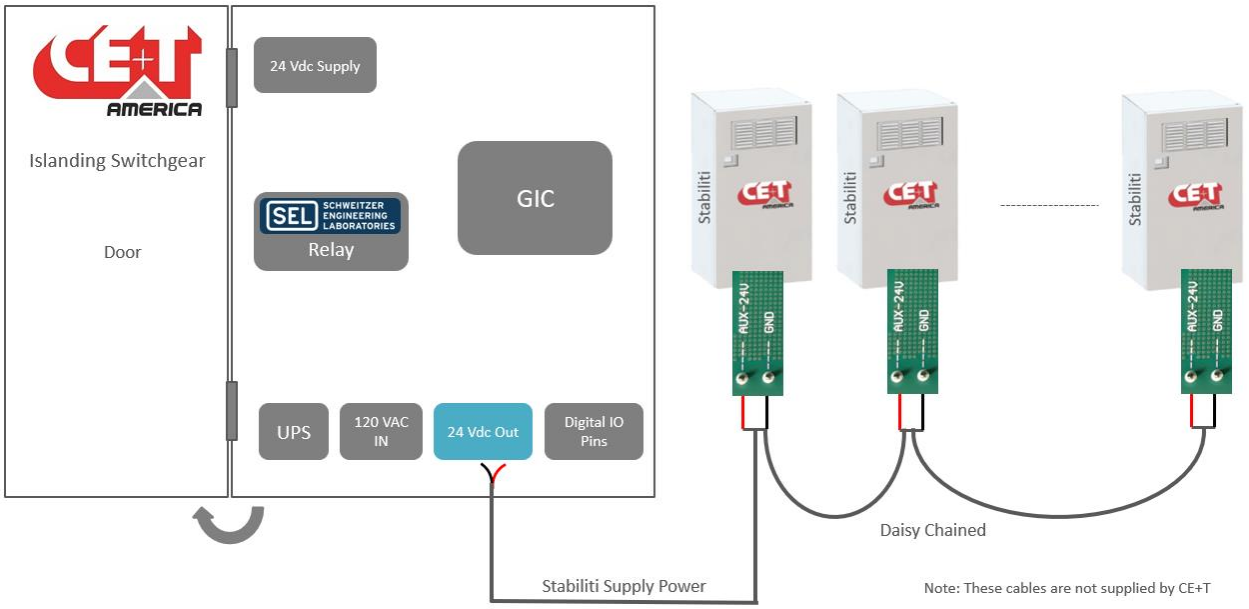


Figure 6 - Field Wiring - Stabiliti Supply Power

13. Field Wiring – Stabiliti Control Wiring

There are two sets of digital control signal which are generated by the SEL namely "Island Command" (Island CMD, Island CMD RTN) and "Island Acknowledge" (Island ACK, Island ACK RTN). These signals are necessary for Stabiliti's reliable microgrid operation. Wiring is daisy chained among all Stabiliti as shown below:

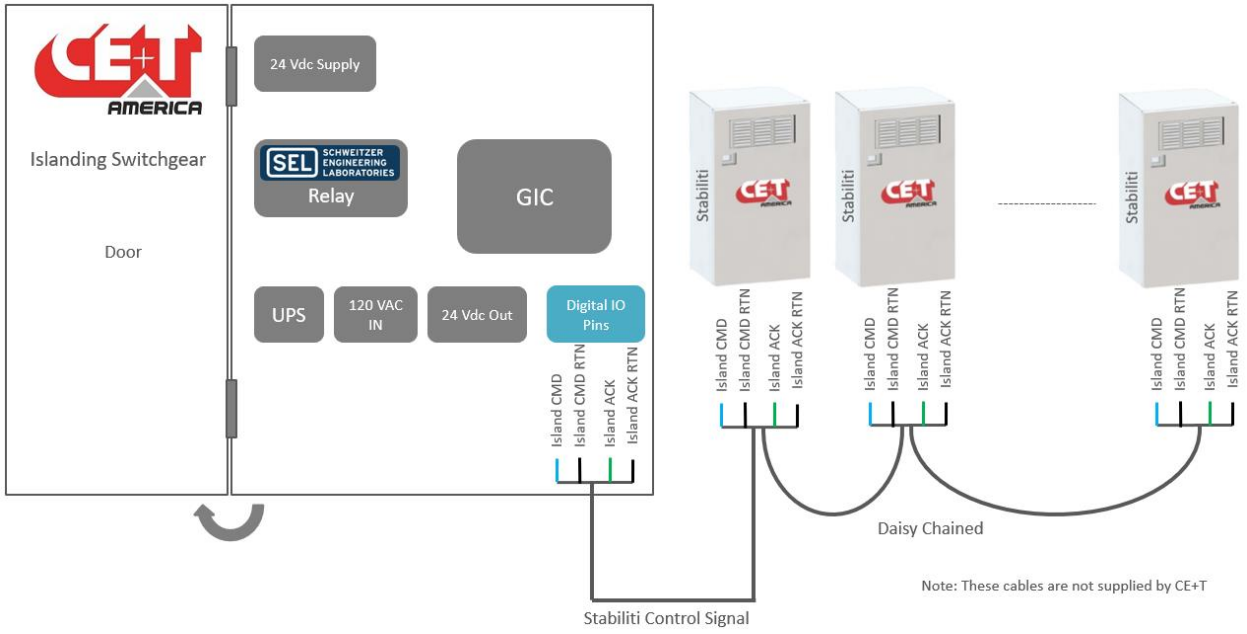


Figure 7 - Field Wiring - Stabiliti Control Wiring

14. Stabiliti Port Settings via Modbus

In addition to using Islanding Switchgear, Stabiliti must have correct AC port settings to be able to form microgrid. For this, AC port must be set to FPWR or "Form Power" (modbus register 65, value of hex 502). Note that merely setting AC port to FPWR does not force Stabiliti to form microgrid. "Island CMD" and "Island ACK" must also be set right by Islanding Switchgear. In addition, Stabiliti's link must be running. This can be done either by setting "System Operation Mode" to "Manual" (register 267, a value of 0 and then a value of 1 to register 263) or by setting "System Operation Mode" to "Auto" (register 267, a value of 1). In Auto mode, link will start automatically if there are no faults in the system.

In addition, note that Islanding Switchgear also provides the 24 Vdc power supply for Stabilti to stay powered through the "Following to Forming" transition.

15. Understanding Islanding Switchgear Panel LEDs

Note that there is no physical display on the Islanding Switchgear. There are two LEDs, one LED indicates presence of grid voltage and the second one indicates whether the AC loads also have voltage (either via grid or via Stabiliti supported microgrid) or not.

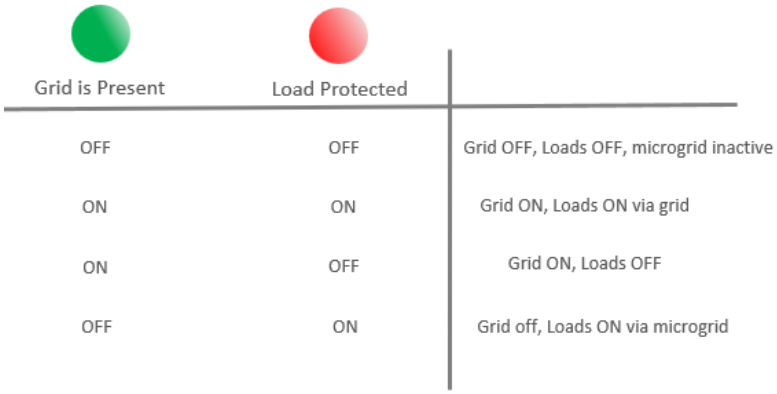


Figure 8 - Panel LED Status Description

16. Site Demonstration – Site Acceptance Tests (SAT)

Before performing a site demonstration, ensure following prerequisites are met:

- Everything is interconnected and installed as per manual, local NEC and NFPA codes
- Stabiliti's are commissioned
- Batteries are sized appropriately. Note that batteries must be sized to support full load on their own. For instance, if the load is 90 kw, ensure there are 4 stabiliti and multiple battery strings rated to run at 100 kw discharge rate for the required amount of back up time.
- Batteries are commissioned as per vendor's instructions and ready to charge/discharge. Leave the SoC around 70 to 90% before starting.
- Load is sized appropriately
- A way to disconnect grid input to the Islanding Switchgear (AC disconnect, not supplied by CE+T).

The SAT setup should look like the one shown below:

The "colored" items (Site controller and utility disconnect switch) will be operated during these tests to verify the complete operation of the system.

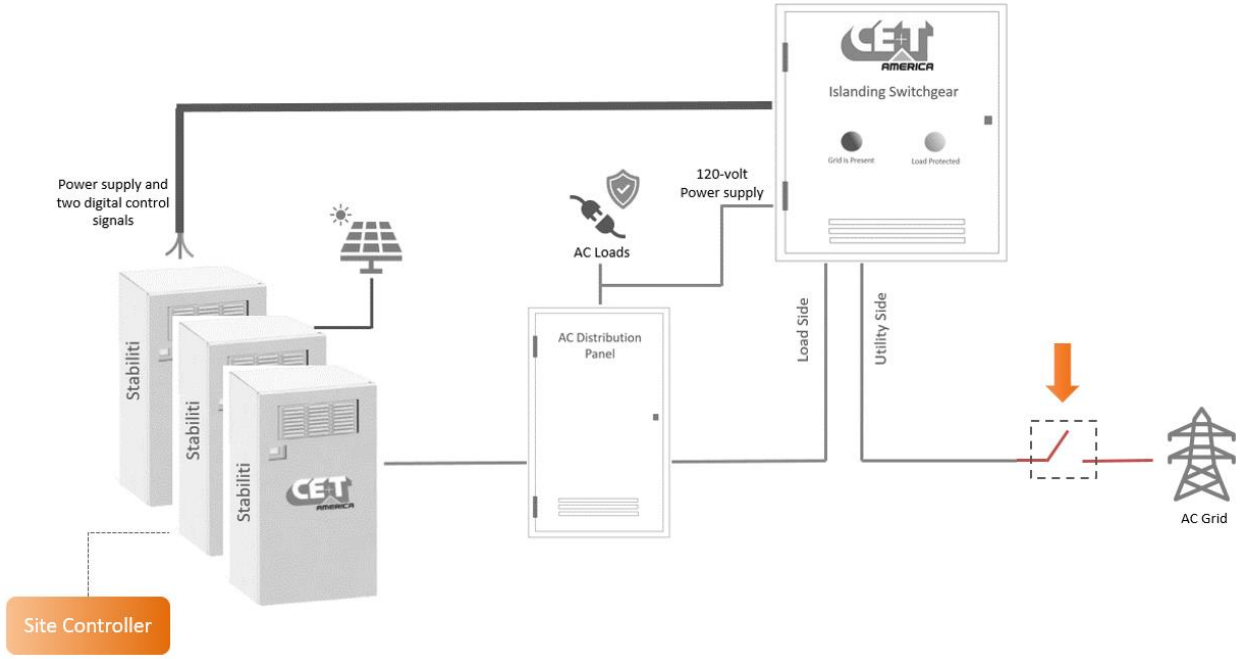


Figure 9 - Site Acceptance Test Setup

Follow the steps listed below:
Note that the two components that will be changed during the tests are the AC disconnect (open or close) and Stabiliti's AC setpoint (for the whole set up. So if the table below says 40 kw and if you have 4 stabiliti, then each stabiliti gets a 10 kw setpoint)

Load size = 90 kw, Number of Stabiliti = 4 (120 kw), Battery Allowable Discharge rate = 100 kw.

	Grid Status (AC Disconnect Status)	Microgrid Status	AC Setpoint	Load Status
1	ON	OFF	0	Grid powered
2	ON	OFF	45 kw	45 kw powered via stabiliti, rest via grid
3	OFF/disconnect open	ON	45 kw	Microgrid powered
4	OFF/disconnect open	ON	0 kw	Microgrid powered
5	ON	OFF	0 kw	Grid powered

Ensure the LED status on the panel matches with actual system operation.

17. Black Start Operation

When the AC loads must be started from a completely off state and there is no grid present, Islanding switchgear can be used to facilitate “Black Start”. To be able to successfully turn on ALL the connected load, ALL Stabiliti must start synchronously at the same time. Even if one Stabilti fail to start, rest of the Stabiliti may not be able to support the inrush current requirements of the load and the AC loads may never turn on.

To seamlessly support black start, Islanding switchgear (ISG) has two toggle switches on the front. These switches are available on 2nd generation Islanding Switchgear. During normal operation (when the black start is not required), the switches must be left in the state shown below:

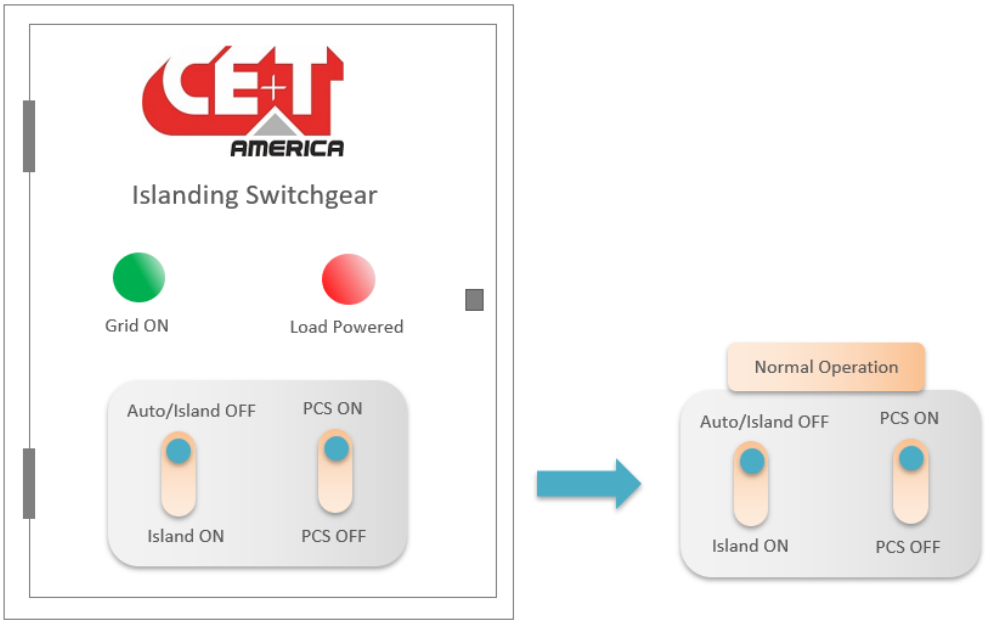


Figure 10 - Black Start - Toggle Switch State - Normal Operation

17.1. Stabiliti Control Power During Black Start

Note that when there is no grid present and when Stabiliti is not running (the LCD panel is on, but Stabiliti is not actively forming microgrid), the source powering the Stabiliti’s control board is a UPS within Islanding switchgear. This UPS is sized to support short duration power to Stabiliti. During grid connected operation, this UPS charges its batteries via grid (120 volts connection). When there is no grid for extended time, the batteries within this UPS may get completely drained. So, ensure there is a way to power on ISG and charge UPS battery within ISG. A portable Diesel genset can also be used for this. Budget 300 watts plus 120 watts for each Stabiliti. So if there are two Stabiliti, you need 540 watts (plus 25% headroom).

Figure 11 - Powering Islanding Switchgear when there is no grid

17.2. Black Start Operation - Assumptions

Black Start operation assumes there is no grid connection, and all AC loads are completely off. To be able to support black start, the Stabiliti must be connected to sufficiently charged batteries capable of supporting both inrush current and steady state operation of connected AC loads. PV can be used as a supplement as well.

Before you start, ensure everything is electrically connected as per local NEC codes, Stabiliti is turned on (the LCD panel on Stabiliti is lit), ISG is turned on and ISG is connected to Stabiliti as per this manual.

17.3. Black Start Initialization

When ready to perform black start operation, follow the sequence of switch operation as shown below. This requires to first ensure the stabiliti is not running, then system must be isolated from the grid, meaning the contactor within islanding switchgear must be forced to operate open and isolate the rest of the system from grid and lastly, when everything is in its right state, black start operation can be performed. The figure below will demonstrate different switch position which will facilitate the transition of the system via these different states.

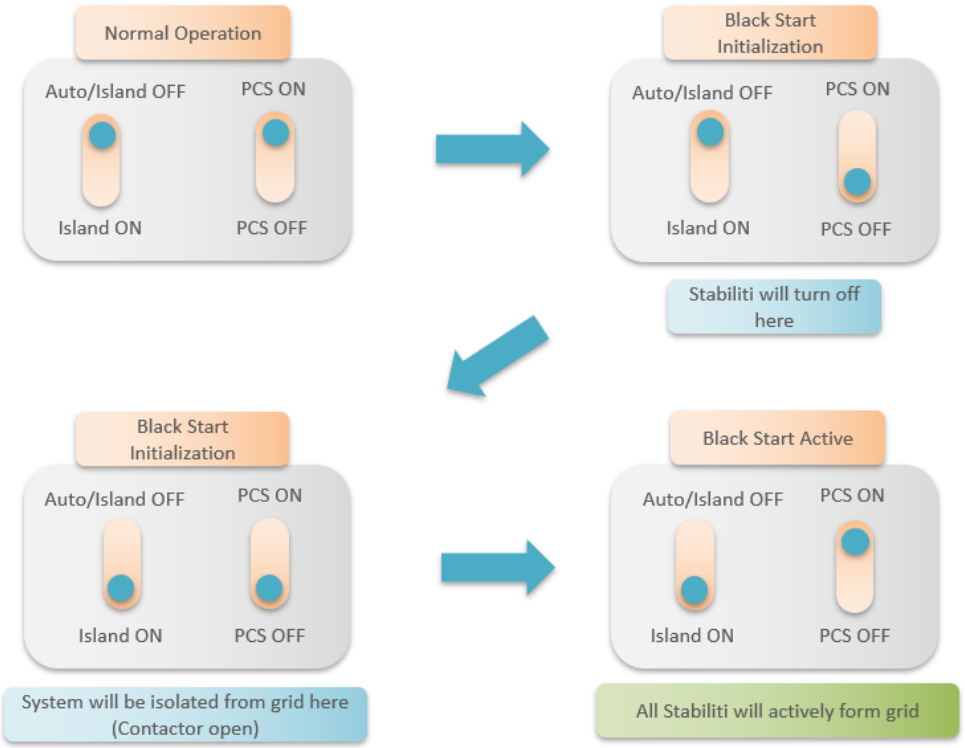


Figure 12 - Black Start - Initialization

17.4. Back to normal operation

When black start operation is complete and system needs to be put back into normal mode, just move first switch to Auto/Island Off position. Microgrid will get synched with the grid when available and inverters will transfer from form to follow (PCSs must be in auto-mode) :

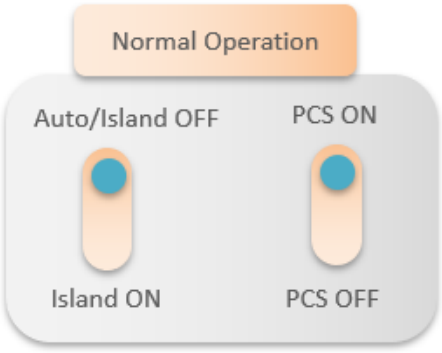


Figure 13 - Switch Position in Normal Operation

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