



# Installation Guide

## Capstone Microturbine® Model C1000S/C800S/C600S with C1000 Series Controller

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# 1. Introduction

This document is intended to provide general installation instructions for a stationary land-based C1000S/C800S/C600S Microturbine. Adherence to this document will help in achieving an efficient and reliable installation. Since this document provides general guidance, modifications may be necessary for site conditions. Installations must comply with locally applicable standards/codes and take into account safety measures further outlined in Section 1.1.

Capstone equipment should be serviced and repaired by Capstone Authorized Service Providers (ASPs) only. The installation and interconnection of this equipment to facility wiring and other equipment must be done by a competent, qualified craftsman that is familiar with applicable standards and codes governing the installation. Installation methods, practices, or procedures that are unauthorized or improperly performed are dangerous and could result in serious personal injury or damage to property and equipment.

## 1.1. Safety Information

This section presents safety information for the user of Capstone Turbine Corporation Microturbines. The user must read and understand this manual before installation of the equipment. Failure to obey all safety precautions and general instructions may cause personal injury and/or damage to the equipment.










The Capstone Microturbine is an advanced power generation system with user and material safety foremost in mind. Fail-safe operation includes mechanical systems, electrical systems, and engine control software.

**It is the user's responsibility to read and obey all safety procedures and to become familiar with these procedures and how to safely install this equipment.**



### 1.1.1. Symbols

The following symbols are used with warnings, cautions, and notes in this document. WARNINGS and CAUTIONs alert you to situations and procedures that can be dangerous to people and/or cause equipment damage. NOTES provide additional information relating to a specific operation or task.









	HIGH VOLTAGE WARNING: Identifies a high voltage hazard that can result in personal injury or death.
	ELECTRIC SHOCK WARNING: Identifies a hazardous voltage area that can cause personal injury or death from electric shock if touched.
	FLAMMABLE MATERIAL WARNING: Identifies a flammable or explosive material hazard that can result in personal injury or death. No open flame or smoking allowed.
	SUFFOCATION WARNING: Identifies asphyxiation hazard that can result in personal injury or death.
	HOT SURFACE/AREA WARNING: Identifies a hot surface or area that can result in personal injury.
	CORROSIVE MATERIAL WARNING: Identifies corrosive material hazard that can result in personal injury.
	ACOUSTIC EMISSIONS WARNING: Identifies sound level hazard that can result in personal injury. Hearing protection is required.
	PACEMAKER WARNING: The turbine generator produces a magnetic field that can be harmful to pacemaker wearers. Pacemaker wearers must stay more than 30 cm (12 in.) away from an operating turbine engine.
	NOTE: Clarifies instructions or highlights important information.

### 1.1.2. General Precautions

The following general precautions must be observed and followed at all times. Failure to do so may result in personal injury and/or equipment damage.

- **Only Capstone Authorized Service Providers are permitted access to the inside of the enclosure.**
- **Do not start or operate the microturbine until after it has been properly commissioned by Capstone Authorized Service Providers.**
- Read and understand the User's Manual before operating the equipment.
- Read and obey all warnings and cautions.
- Use appropriate personal protective equipment (PPE) when handling fuel or other corrosive material.
- Make sure all fuel connections are tight, free from leaks, and protected from damage.
- Make sure all electrical connections are tight, clean, dry, and protected from weather and damage.
- The microturbine may be equipped with a heat recovery system. Use caution around relief valves where hot water and steam may be present.
- Use hearing protection when you work on or near an operating microturbine for extended time periods.
- Keep the equipment clean.
- Keep all flammable materials away from the microturbine and its components.
- Do not operate or work on the equipment if mentally or physically impaired, or after consumption of alcohol or drugs.
- Keep an ABC rated fire extinguisher near the microturbine.
- Obey all applicable local, state, and national codes and regulations.







### 1.1.3. Electrical Precautions

	<p> <b>ELECTRICAL WARNING</b></p> <p>HIGH VOLTAGE! Obey all safety procedures when you work around electrical equipment. Failure to observe this warning can result in serious injury or death.</p>
	<p> <b>ELECTRICAL WARNING</b></p> <p>ELECTRIC SHOCK! Make sure the system is off and the dedicated disconnect switch is in the open position and is locked. Failure to observe this warning can result in serious injury or death.</p>
	<p> <b>ELECTRICAL WARNING</b></p> <p>Consult all applicable codes and industry standards before connecting the interface wiring for the microturbine. A qualified electrician may be required to perform this work. Failure to observe this warning can result in personal injury or equipment damage.</p>
	<p> <b>ELECTRICAL WARNING</b></p> <p>The turbine generator produces a magnetic field that can be harmful to pacemaker wearers. Pacemaker wearers must stay more than 30 cm (12 in.) away from an operating turbine engine.</p>

The output voltage and residual capacitor voltage of this equipment is dangerous. Use caution when you work on electrical equipment. The microturbine system can include multiple sources of power. Make sure to turn off the system and lock out all sources of power prior to doing any work on the equipment.

- Open and lock the dedicated disconnect switch to isolate the microturbine from the electric utility grid or loads.
- If the microturbine is equipped with battery packs, open the battery isolation switches and unplug the battery cables.
- Wait ten (10) minutes for any capacitive stored voltage to dissipate.
- Always disconnect all power sources.
- Use a voltmeter to make sure that all circuits are de-energized.
- All output connections must be made in accordance with applicable codes.

#### 1.1.4. Fuel Precautions

	<p style="text-align: center;"> <b>WARNING</b></p> <p>FLAMMABLE MATERIAL! Microturbine fuel is flammable and explosive. No open flame or smoking is allowed near the microturbine. Failure to observe this warning can result in personal injury or equipment damage.</p>
	<p style="text-align: center;"> <b>WARNING</b></p> <p>CORROSIVE MATERIAL! Gaseous fuels can be corrosive. Concentrations of Hydrogen Sulfide (H<sub>2</sub>S) can be found in sour natural gas and sour high BTU gas. Minimize exposure to gaseous fuels and provide sufficient fresh airflow around equipment. Failure to observe this warning can result in personal injury.</p>
	<p style="text-align: center;"><b>CAUTION</b></p> <p>Do not connect to any fuel source other than the fuel specified for use by the microturbine. Failure to observe this caution can result in equipment damage.</p>
	<p style="text-align: center;"><b>CAUTION</b></p> <p>Make sure that fuel inlet pressure does not exceed the maximum rated pressure specified on the microturbine labeling. Failure to observe this caution can result in equipment damage.</p>

The Capstone Microturbine operates on approved gaseous or liquid fuels only. Use appropriate PPE when handling fuel. Keep flames, sparks, pilot lights, equipment that produces electrical arcs, switches or tools, and all other sources of ignition away from areas where fuel and fumes are present. If there is a fire, use a multi-purpose dry chemical or CO<sub>2</sub> fire extinguisher, and contact the appropriate fire officials.

Fuel lines must be secure and free of leaks. Fuel lines must also be separated or shielded from electrical wiring. If you smell fuel fumes, immediately stop operation of the equipment, close the fuel isolation valve, and locate and repair the source of the leak or call a qualified professional.

Make sure to isolate the fuel supply prior to doing any work on the equipment.

## 1.2. Referenced Documents

Table 1 presents a list of Capstone documents referenced in this Installation Guide.

**Table 1. Referenced Documents**

Number	Description
<b>Product Specifications</b>	
460089	Signature Series Product Specification
460080	C1000S Product Specification
<b>Technical References</b>	
410002	Capstone MicroTurbine Fuel Requirements Technical Reference
410014	CRMS Maintenance Edition Technical Reference
410065	Capstone MicroTurbine Systems Emissions Technical Reference
410071	Dual Mode System Controller Technical Reference
410108	C1000S/C800S/C600S Technical Reference
410115	Grid Interconnect Technical Reference
<b>Application Guides</b>	
480002	Biogas Application Guide
480034	Liquid Fuel Application Guide
480035	High Humidity Application Guide
480057	LPG Application Guide
<b>Installation Guides</b>	
480055	Raw Natural Gas Application Guide
480067	C1000S Inlet Hood Installation Guide
480068	C1000S Latch and Striker Plate Installation Guide
480069	C1000S Exhaust Rain Cap Installation Guide
<b>Work Instructions</b>	
440216	Main Battery Replacement - Capstone Model C200/C1000 Series
440297	Desiccant Kit Replacement Work Instruction
440289	Locked Rotor Identification Work Instruction
440404	Capstone C1000 Signature Series Microturbine Standard Maintenance Schedule
<b>Forms</b>	
420008	New System Condition Report
460006	Commissioning Checklist

**Table 1. Referenced Documents (Continued)**

Number	Description
<b>Drawings</b>	
533032	C1000 Liquid Fuel Pretreatment P&ID
534054	C1000S (with C800S/C600S) Industrial Package Outline and Installation (O&I) Drawing
534462	C1000 MultiPac Sync
534473	C1000S Mechanical Coordination Diagram
534788	C600S Industrial Package Outline and Installation (O&I) Drawing
534885	C800S Industrial Package Outline and Installation (O&I) Drawing
534895	C1000S Industrial Package Outline and Installation (O&I) Drawing

### **1.3. Disclaimer**

Information in this publication represents data available at the time of print. Capstone Turbine Corporation reserves the right to change this publication and the products represented without notice and without any obligation or liability whatsoever.

All instructions and diagrams have been checked for accuracy and simplicity of application. However, the skills of the installer are most important. Capstone Turbine Corp. does not guarantee the result of any installation contained in this manual. Nor can Capstone Turbine Corp. assume responsibility for any injury or damage to property. Persons engaging in installation do so entirely at their own risk.

### **1.4. C1000S/C800S/C600S Models**

The package design of each C1000S/C800S/C600S model is built around a number of 200 kW microturbine bays. The C1000S contains five microturbine bays for 1000 kW output, the C800S contains four microturbine bays for 800 kW output, and the C600S contains three microturbine bays for 600 kW output. Most attributes of the turbine assembly other than power output are identical across all models. Figure 1 shows the C1000S/C800S/C600S models in their respective enclosures. Existing models also include the 800S and 600S in a five-bay package as shown in Figure 2.

**C1000S Assembly**



**C800S Assembly**



**C600S Assembly**



**Figure 1. C1000S/C800S/C600S Models**

**C800S Assembly**



**C600S Assembly**




**Figure 2. C800S and C600S Models in Five Bay Enclosure**



## 2. Microturbine Handling

### 2.1. Receiving and Inspection

All Capstone Microturbines are inspected and covered with protective packaging before leaving the factory. Upon receipt, inspect the packaged items for shipping damage. Preserve the shipping desiccant by leaving the polyethylene wrapping on the microturbine as long as possible prior to installation. If you must remove the packaging for inspection, contact your Capstone Authorized Service Provider for information regarding warranty implications. Do not destroy or discard packaging materials. Reinstall packaging after initial inspection and before placing system into storage. For initial inspection purposes or maintenance tasks during storage, carefully remove original packaging/crating. If the microturbine must be stored prior to installation, refer to Section 2.2 for maintenance requirements during storage.

	NOTE
	The majority of Capstone Microturbines are shipped Ex-Works, therefore Capstone is no longer responsible once a Microturbine has been loaded for shipment. Many carriers only offer a modest insurance coverage based on bulk weight and may not cover the full cost of the Microturbine. Please check with your preferred freight carrier to determine if additional insurance is required to cover the full replacement cost of the Microturbine prior to shipment.

#### 2.1.1. Damage Reporting

If any damage is evident, note the damages on the shipping documents and the New System Condition Report (Table 1), immediately file a claim with the carrier, and notify your Capstone Distributor. Save all packing materials until you determine that all items have arrived in good condition, as packing materials will need to be given to the shipping company for inspection for any insurance claims to be approved.

#### 2.1.2. Loose-Shipped Items

Shipping places dimensional constraints on the C1000S/C800S/C600S enclosure. In order to remain within these parameters and to protect against damage during shipment, the items listed below are shipped “loose,” i.e. not installed to the system.

- Door latches and striker plates (included in enclosure)
- Exhaust flappers (included in enclosure)
- Air inlet hood assemblies (in separate crate)

Installation instructions for any accessories that may be shipped with the unit, e.g. heat recovery module, may be found in the accessory’s installation guide.

## 2.2. Storage

If your C1000S/C800S/C600S microturbine must be stored for a period of time, the following precautions for storage and removal from storage will help to minimize corrosion and deterioration. The C1000S/C800S/C600S microturbine can be stored without any preparation, provided that the units are placed in an environment that meets the environmental operating conditions defined in the C1000S Product Specification (Table 1). Follow the storage instructions defined in C1000S Series Microturbine Standard Maintenance Schedule and Procedures (Table 1).

### 2.2.1. Basic Storage Requirements (Up to 6 Months)

- Keep the system as dry as possible. Prevent moisture from entering the protective packaging. Desiccants are provided inside the enclosure to reduce humidity while in storage.
- Batteries should be ordered separately from the system, and thus can have easy access to be maintained. Refer to Battery Maintenance in C1000S Series Microturbine Standard Maintenance Schedule and Procedures (Table 1).
- Store the system at temperature between -40 °C (-40 °F) and 65 °C (149 °F), and at relative humidity of 40 percent or less, if possible.

### 2.2.2. Extended Storage Requirements (Longer than 6 Months)

- Perform the tasks listed under Basic Storage Requirements above.
- If the unit will be in long term storage before use, the microturbine must be ordered without the batteries. The batteries, ordered separately, will be shipped in time for commissioning. Refer to the Main Battery Replacement - Capstone Model C200/C1000 Series (Table 1) to install the batteries.
- For maintenance tasks during extended storage, carefully remove original packaging/crating. Do not destroy or discard packaging materials. Reinstall packaging between maintenance activities while system is in storage. Intake and exhaust sealing caps for desiccant MUST remain installed during storage, except as necessary to replace desiccant.
- If storage time will extend beyond six months, replace desiccant and perform manual engine rotation check at the beginning of extended storage time. Refer to Desiccant Kit Replacement Work Instruction (Table 1) and Locked Rotor Identification Work Instruction (Table 1).
- Replace desiccant and perform manual engine rotation check every 12 months and any time intake and exhaust sealing caps are removed. Refer to Desiccant Kit Replacement Work Instruction (Table 1) and Locked Rotor Identification Work Instruction (Table 1).
- Keep system as dry as possible. Prevent moisture from entering protective packaging.
- In high humidity conditions (greater than 60 percent relative humidity continuous long term), consult with local commercial water damage prevention and remediation providers to prepare/preserve system(s) for high humidity conditions.

- Repack system in original packaging/crating or equivalent before shipping system to final installation site.

### 2.2.3. Non-Operation

- For liquid fuel systems: Purge all fuel from system before storage.
- Observe the following guidelines to prevent over-discharging system batteries.
  - If the microturbine will be in Stand Alone sleep state for more than five days, Capstone recommends the following:  
Disconnect the UCB battery from UCB connector J13 in each microturbine bay.  
Disconnect the UPS battery from the UPS in the C1000 series controller.
  - If the microturbine will not be operated for a period of greater than two weeks, or if the microturbine is to be serviced or transported, the battery isolation switch (battery breaker) should be set to OFF. Lock the switch in place using the battery switch bolt as shown in Figure 3.
- If the microturbine will not be operated for a period of greater than one month, isolate the engines and install desiccant.
- Isolate engines if connected to a common exhaust with operating systems if the microturbine will not be operated for a period of 48 hours. Refer to Section 5.4.5.2.

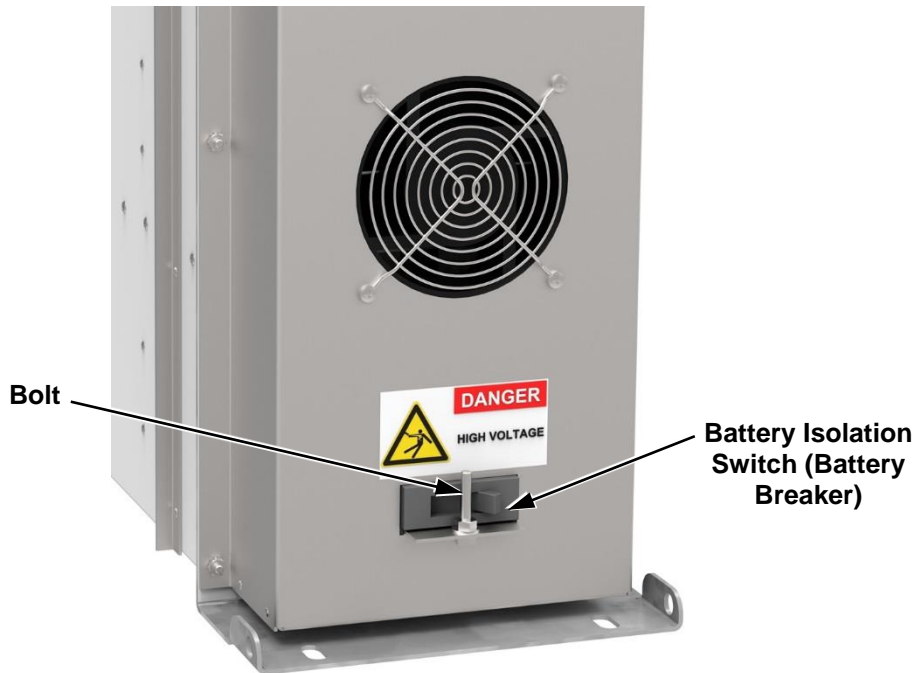

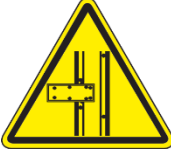
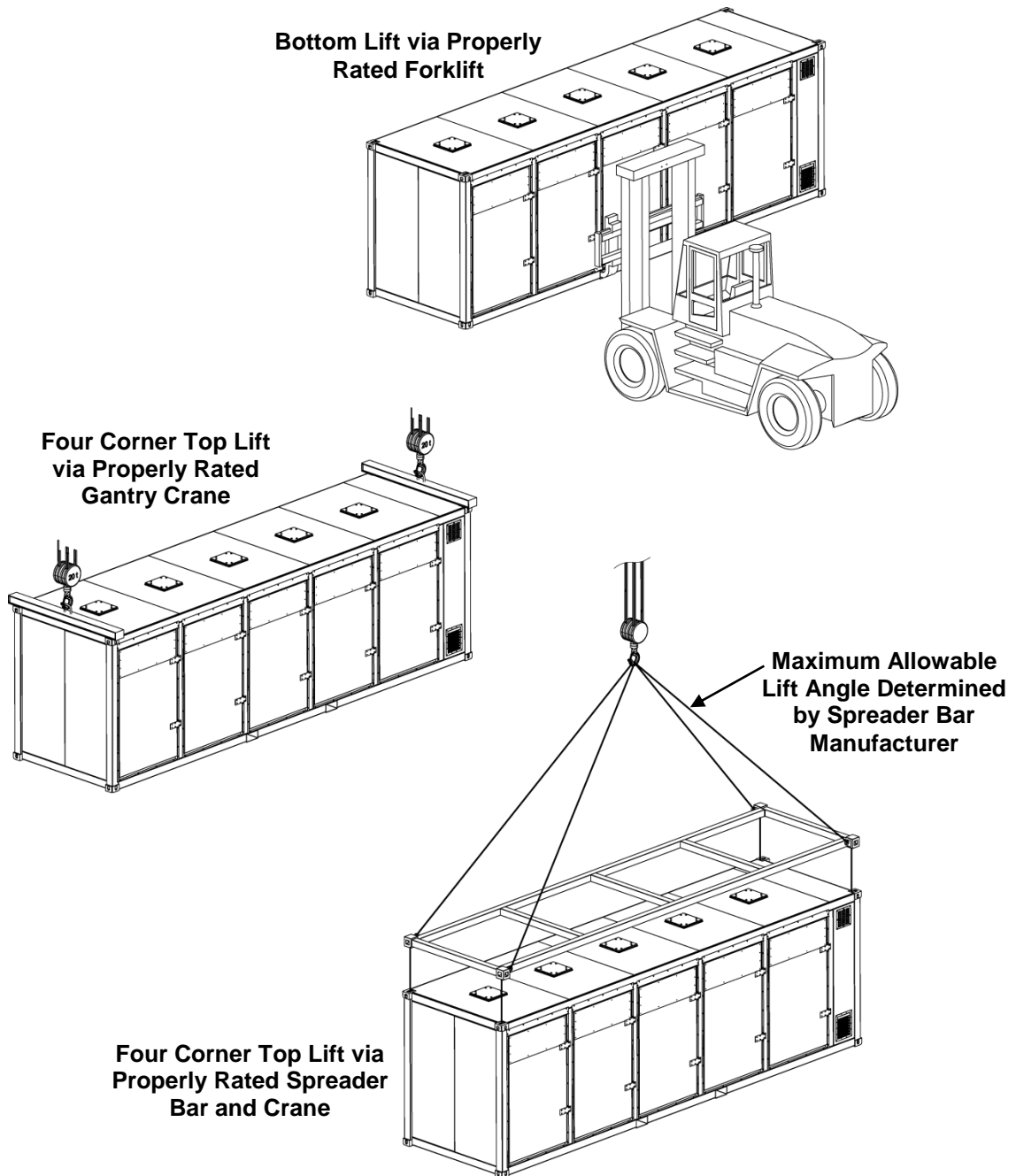


Figure 3. Locking the Battery Isolation Switch

## 2.3. Rigging

	<div data-bbox="748 270 1040 317" style="background-color: #FFD700; text-align: center; padding: 5px;"><b>⚠ WARNING</b></div> <p>Drop danger! Exercise extreme care when lifting/handling the system.</p> <ul style="list-style-type: none"> <li>• Keep all nonessential personnel clear of the lifting area at all times.</li> <li>• Proper rigging must be provided during lifting for stability.</li> <li>• If lifting at corner castings, spreader bars are required.</li> <li>• When lifted using fork pockets, support must be provided all the way through.</li> </ul>
	<div data-bbox="784 569 1005 615" style="background-color: #FFFF00; text-align: center; padding: 5px;"><b>CAUTION</b></div> <p>Blanking plates must be installed during lifting. Failure to observe this caution can result in equipment damage.</p>

See Figure 4 for recommended lifting equipment. Refer to the O&I drawing (Table 1) for all dimensional information, weight and center of gravity of the system. The C1000S/C800S/C600S enclosure features a base with forklift pockets located at both sides in the center. The system can be moved using a forklift or overhead crane provided the equipment is rated for the load. When using a forklift, the forks must be of adequate length to support the unit. Place the forks correctly so as to not damage the base of the unit. The system can be forked from any side when it is completely empty or fully populated, otherwise, it must be lifted from the heavy side only. When using a crane, ensure that all chains/cables and spreader bars are connected correctly for safe handling. Chains/cables shall not exceed the lift angle specified by the spreader bar manufacturer. If necessary, use guide ropes to prevent swinging and turning.



**Figure 4. C1000S/C800S/C600S Lifting Example**

## **2.4. Assembly**

Before operation, the following components must be installed on the C1000S/C800S/C600S enclosure:

- Door latches and striker plates. Refer to the C1000S Latch and Striker Plate Installation Guide (Table 1).
- Exhaust flappers. Refer to the C1000S Exhaust Rain Cap Installation Guide (Table 1).
- Air inlet hood assemblies. Refer to the C1000S Inlet Hood Installation Guide (Table 1).

### 3. Site Considerations

Select the site for your microturbine using the following criteria:

- Structure that the microturbine will be set upon must be strong enough to support the weight of the microturbine, accessories, and other equipment mounted on the structure. It must also support the weight of any service personal and equipment. A concrete pad is recommended.
- Structure shall allow proper mounting and support; including wind load and seismic requirements.
- Area should provide easy access for installation, maintenance, and repair. Area should provide adequate service clearances for general maintenance and inspections, overhauls, and component removal/replacement. Refer to the C1000S, C800S, or C600S O&I Drawing (Table 1).
- Area should be kept clean and dry, and have adequate drainage.
- Area should be protected from adverse weather conditions (flooding, fire, icing, etc.).
- Area should be protected from vandalism, birds, rodents, and other small animals.
- Exhaust gas should be piped away from any ventilation intakes.
- Area shall meet all national and local code requirements.
- Future expansion plans should be considered when designing layout.

#### 3.1. Climatic Conditions

Microturbine installations tend to see a wide range of climatic conditions. While the product may be designed to function effectively in a majority of these conditions, additional considerations are required for adverse climatic conditions.

##### 3.1.1. Coastal and Humid Environments

Salinity of the air and condensation due to the higher humidity may cause corrosion on standard industrial packaged systems. High humidity systems are mandatory for humid and coastal environments, as they offer additional corrosion resistance. Refer to the C1000S/C800S/C600S Technical Reference (Table 1) for more information.

##### 3.1.2. Arid/Dusty Climates

Excessive airborne particulates — dust, sand, plant material such as pollen — pose threats for maintenance and operation of a microturbine. Protective features such as screening filters for ventilation air are recommended. It should be noted that such filters add restriction to the air flow. As a result, larger openings for the air to enter and leave the installation site will be required. The total restriction, including filters, must remain below the total allowed restriction listed in the C1000S Product Specification (Table 1).

If ventilation filters are used, there should be provisions in place to monitor their condition and detect clogging. For example, pressure drop indicators can be installed on the room ventilation system. Please consult your Capstone authorized distributor for more information.

Standard factory electronics air filters are rated for 90% average efficiency on 20 micron, which filters larger particulate matter and insects but does not protect against fine particulates. Fine particulate matter can settle on electronics surfaces. This reduces heat transfer capacity which can cause damage to system components. For sites where fine particulate matter is prevalent, additional filtration may be needed.

To help ensure proper operation and prevent damage to equipment, observe the following recommendations:

- Microturbine performance is dependent on the inlet air temperature and pressure loss, so care should be taken in selecting the size and location of any supplemental filtration to minimize any potential performance losses.
- Filters and ducting should be oversized to limit the pressure loss to the microturbine. The differential pressure sensor measures pressure drop across the air filter to monitor filter state.
- Since standard factory engine air filters are rated for Minimum Efficiency Reporting Value (MERV) 13, they will capture the fine dust particles of concern to the engine. In high particulate environments, the filters can clog quickly, which impacts site operation and maintenance schedules, causes reduced power output, and other system problems.
- Filters must be properly maintained. If a filter fails from extended usage while clogged, any damage caused by particle ingress may not be covered by warranty. Elevated particulates such as dust and sand in the environment will shorten the maintenance intervals for air filters used in the microturbine, resulting in higher maintenance costs as well as internal warnings and faults. If a microturbine air filter becomes clogged, an internal fault will occur.
- Ensure that lighting at a site is properly placed. Lighting provided at the air inlet could attract insects and clog the filters.

### **3.1.3. Temperature Extremes**

Extreme temperatures can affect the performance of the microturbine. Note the ambient ratings for the microturbine are stated in the C1000S Product Specification (Table 1). For very cold extremes, a housing may be required if the microturbine is to be exposed to these conditions. High temperatures de-rate performance. Refer to the C1000S/C800S/C600S Technical Reference (Table 1), Performance section, for accurate de-rate information.

### **3.1.4. High Altitudes**


At higher altitudes air density is reduced, which results in a lower mass flow, reducing the power output of the microturbine. Refer to the C1000S/C800S/C600S Technical Reference (Table 1), Performance section, for accurate de-rate information.



## 3.2. Compliance, Standards and Codes

Since the microturbine produces electricity up to 480 V (defined by the National Electrical Code as low voltage, having 600 V or less), and since it is a gas-powered device, installation usually requires one or more permits from local regulatory bodies or grid interconnection approval through the local utility. Capstone microturbines also carry a number of third-party certifications.

Microturbines are fundamentally low emissions generation technology, but may be subject to exhaust emissions regulations on a local level, national level, or both. Compliance with emissions regulations usually requires special permits. Check with the local air quality agency early in the design phase of any project for permitting requirements. More detailed information regarding microturbine exhaust emissions can be found in the Emissions Technical Reference (Table 1). Contact your local distributor for best-practice recommendations on air emissions permitting in your region.

	<b>NOTE</b>
	<p>Standards and codes vary by municipality, region, country, and application. For example, some areas may require a certificate-of-need, zoning permit, building permit or other site-specific certificate. Check with all local government authorities early in the planning process to establish requirements. Check back periodically for updates.</p> <p>Compliance with all applicable local and national codes is the responsibility of the installer.</p>

### 3.2.1. Microturbine Certifications

Capstone products are designed and certified to meet specific standards. The following standards apply. Refer to the C1000S/C800S/C600S Product Specification (Table 1).

- Underwriters Laboratories (UL 2200)
- CE Certification
  - 2014/30/EU EMC Directive
  - 2006/42/EC The Machinery Directive
  - 2014/68/EU PED Directive
- Compliant with the following grid interconnection standards:
  - Underwriters Laboratories (UL 1741SA)
  - Bundesverband der Energie- und Wasserwirtschaft (BDEW TR3)
  - Verband der Elektrotechnik (VDE AR N 4105)
  - Comitato Elettrotecnico Italiano (CEI 0-16)

### **3.2.2. Grid Interconnection Planning**

The following paragraphs contain guidelines and requirements for connecting a microturbine installation to a utility grid.

#### **3.2.2.1. Feasibility Study**

Economic analysis should consider local utility tariffs or competitive prices, interconnection fees, permit approval activities, and consulting services for Capstone applications. These expenditures vary depending on the number of the Capstone units, geographical location, and the utility company.

Capstone units are certified for safe utility interconnection by Underwriter's Laboratories (UL), the states of New York and California, Verband der Elektrotechnik (VDE-AR-N 4105), Bundesverband der Energie- und Wasserwirtschaft (BDEW TR3), and Comitato Elettrotecnico Italiano (CEI 0-16). These interconnect certifications mean that the process can take less time than for uncertified generators, and should therefore be less costly to customers. Refer to the Grid Interconnection Technical Reference (Table 1).

Factors impacting the interconnect process are as follows:

- Number of microturbine units proposed
- Nature of the grid at point of connection
- Power distribution or Point of Common Coupling (PCC) voltage level
- Requirements of the specific utility company
- Electric load to be supplied
- Power quality parameters such as voltage sagging, flicker, harmonic distortions
- Other Distributed Generation (DG) systems operating on premises, in parallel with the grid
- Utility and state regulations in the region

#### **3.2.2.2. Timeline Planning**

Microturbine installation and interconnection with a utility for parallel operation should not present technical difficulties. However, utilities are sensitive to interconnection issues due to their legal obligation to provide power to their customers. Therefore, utilities will often require a thorough, methodical approach for new generator interconnections. Establishing realistic timeframes and duties will facilitate smooth implementation, maintain good relations, and minimize potential delays.

Technical factors that can impact the interconnect review process or determine which utility interconnect plan applies include the following:

- Distribution system at the PCC
- Size of generation facility in relation to the capacity of the utility feeder
- Export capacity, as a percentage of feeder or line section peak load

### 3.2.2.3. *Project Design*

A qualified engineering firm or a consultant, in compliance with local, state, and national codes and regulations, shall design an application which shall be in compliance with local, state, and national electrical regulations including the National Electrical Code (NEC). A one-line diagram and a plan are minimally required in an interconnect application.

### 3.2.2.4. *Interconnect Application*



## NOTE

Insufficient or incomplete information can cause a delay or rejection of the application.

The typical application process includes the following:

- Initial Communication: inquiry for an application
- Completion and submission of the application forms, documents, and initial review fees
- The utility will prepare an Interconnection Agreement upon acceptance.

In addition, the following are normally required:

- A single-line diagram showing the electrical relationship and descriptions of the significant electrical components such as primary switchgear, secondary switchboard, protective relays, transformers, generators, circuit breakers, with operating voltages, capacities, and protective functions of the generating facility, customer's loads, and interconnection with the utility distribution system.
- Site plans and diagrams showing the physical relationship of the significant electrical components of the generating facility such as generators, transformers, primary and secondary switchboard, and control panels, customer's loads and the interconnection with the utility distribution system.
- Transformer information — voltages, capacity, winding arrangements, taps connections, impedance — if used to interconnect the generating facility with the utility distribution system.
- In the case of Dual Mode applications, it may be necessary to provide information on the transfer switching scheme or the Capstone DMSC, including capacity rating, technical and operational description.
- A disconnect device, with visible open circuit, shall be provided and shown in submittals, with specific brand, catalogue number, and rating, for each microturbine output line, for utility company approval as a safety means for preventing any feedback to the grid during maintenance or repair work on the grid, upstream of the microturbine.

### 3.2.2.5. *Application Review by Utility Company*

The utility conducts a review of the design package to ensure that the plans and design satisfy the goal of attaining a safe, reliable, and sufficient interconnection and will satisfy the technical requirements for interconnection. Site-specific tests may be required prior to final authorization.

### **3.2.2.6. *Interconnect Agreement***

The utility provides the executable standardized interconnection contract, metering agreement, and power purchase agreement, appropriate for the DG application and desired mode of operation. These documents clarify roles and responsibilities between the utility and customer and specify any additional power systems modifications, metering, monitoring, or protection devices necessary to accommodate the DG project in the utility distribution system.

The agreements establish responsibilities, completion schedules, and estimated or fixed price costs for the required work. Execution of these agreements indicates approval to proceed with the installation or to perform the construction work related to the interconnection.

### **3.2.2.7. *Start-Up and Tests***

During the start-up process, a utility company may request a demonstration of certain capabilities related to parallel operation with the grid. Such a demonstration can include response to grid outage, and response to grid anomalies. In Dual Mode applications, islanding with isolated load and returning in parallel mode may be required to demonstrate and test the Capstone Dual Mode System Controller (DMSC).

These tests will require advance preparation including a written procedure and coordination with the utility.

## 4. Customer Connections

See Figure 5 for the location of the customer connections to the C1000S/C800S/C600S microturbine.

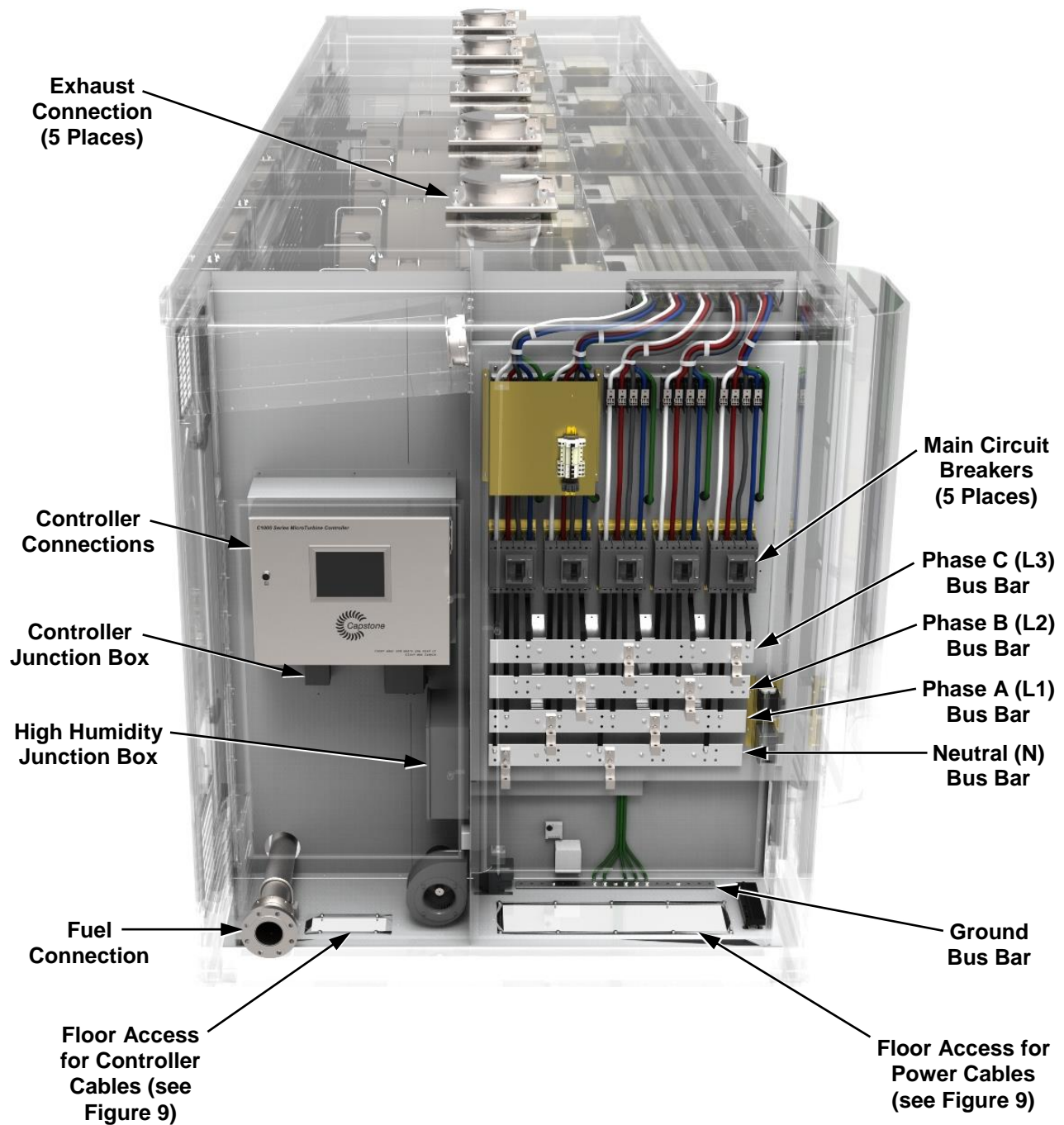


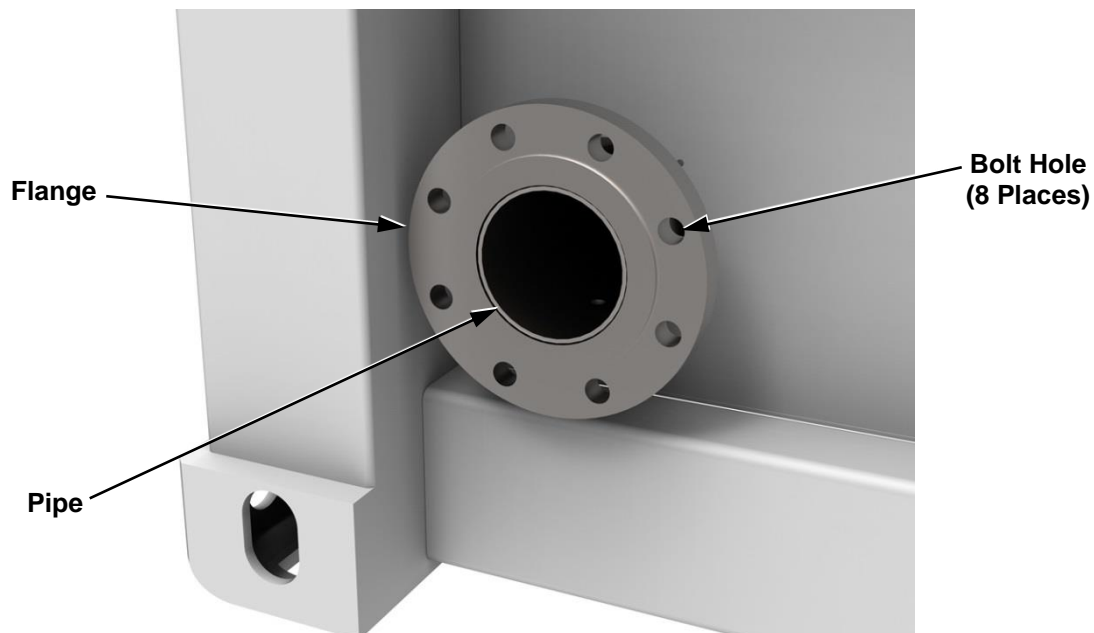
Figure 5. C1000S/C800S/C600S Connections

## 4.1. Fuel Connection

Refer to Table 2 and Table 3 for fuel connection specifications. The customer fuel connection is shown in Figure 6 for gaseous fuels and Figure 7 for liquid fuels. Refer to C1000S, C800S, or C600S O&I Drawing (Table 1) for further details.

**Table 2. Gaseous Fuel Connection Specifications**

Parameter	Specification
Pipe Diameter	102 mm (4 inch)
Flange: Type Diameter	ASME/ANSI B16.5 Class 150 (Raised Face) 229 mm (9 inch)
Bolt Holes: Size Bolt Circle	19 mm (3/4 inch) for 16 mm (5/8 inch) bolt 191 mm (7.5 inch)
Recommended Torque	136 Nm (100 ft-lb)
Pressure: Natural Gas, High Pressure Natural Gas, Low Pressure	534 $\pm$ 17.2 kPag (77.5 $\pm$ 2.5 psig) 18.1 $\pm$ 16.4 kPag (2.63 $\pm$ 2.38 psig)
Fuel Pressure Fluctuation	1 psi/sec



**Figure 6. Gaseous Fuel Connection**

**Table 3. Liquid Fuel Connection Specifications**

Parameter	Specification	Torque	Pressure
Fuel Supply Header	1 1/2 inch FNPT	286 Nm (211 ft-lb)	3.4 to 34.5 kPag (0.5 to 5.0 psig)
Fuel Return Header	3/4 inch FNPT	106 Nm (78 ft-lb)	34.5 kPag (5.0 psig) maximum
Skid Drain Header	1/2 inch FNPT	73 Nm (54 ft-lb)	Atmosphere
Filter Drain Header	1/2 inch FNPT	73 Nm (54 ft-lb)	Atmosphere



**Figure 7. Liquid Fuel Connection**

## 4.2. Exhaust Connection

### 4.2.1. Exhaust Specifications

Exhaust connection requirements are as follows:

- Exhaust diameter: 305 mm (12 inch) outer diameter
- Exhaust ducting material to be rated to 371 °C (700 °F)
- Maximum allowable backpressure:
  - Low emissions: 1245 Pa (5 in WC)
  - All other: 1990 Pa (8 in. WC)
- Loading: not more than 22.7 kg (50 lb) per bay

### 4.2.2. Rain Cap Removal

Remove the rain cap from the exhaust outlet assembly (Figure 8) by loosening the clamp ring, which is secured by a hex screw and nut. The screw or nut can be adjusted using a 9/16-in. wrench.

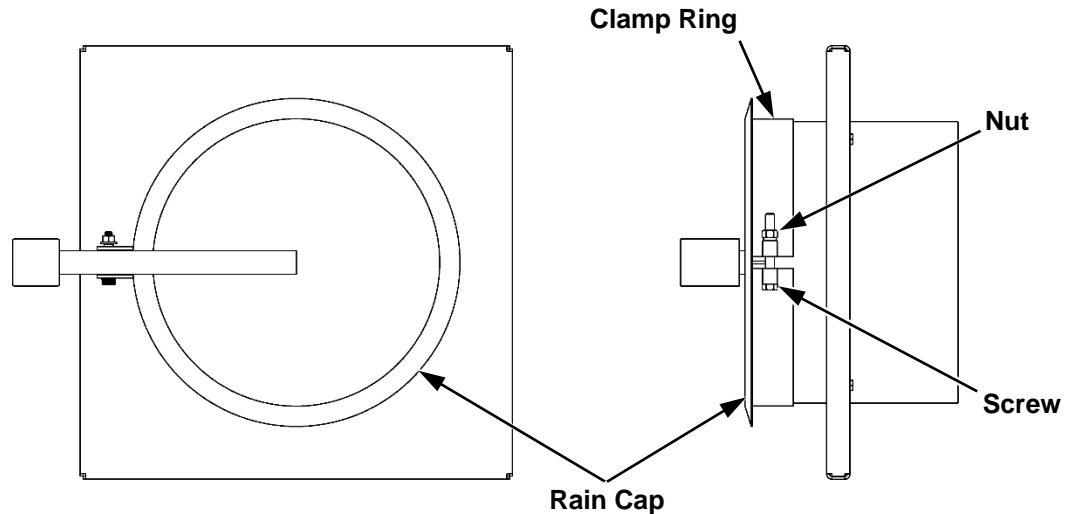


Figure 8. Exhaust Outlet Assembly

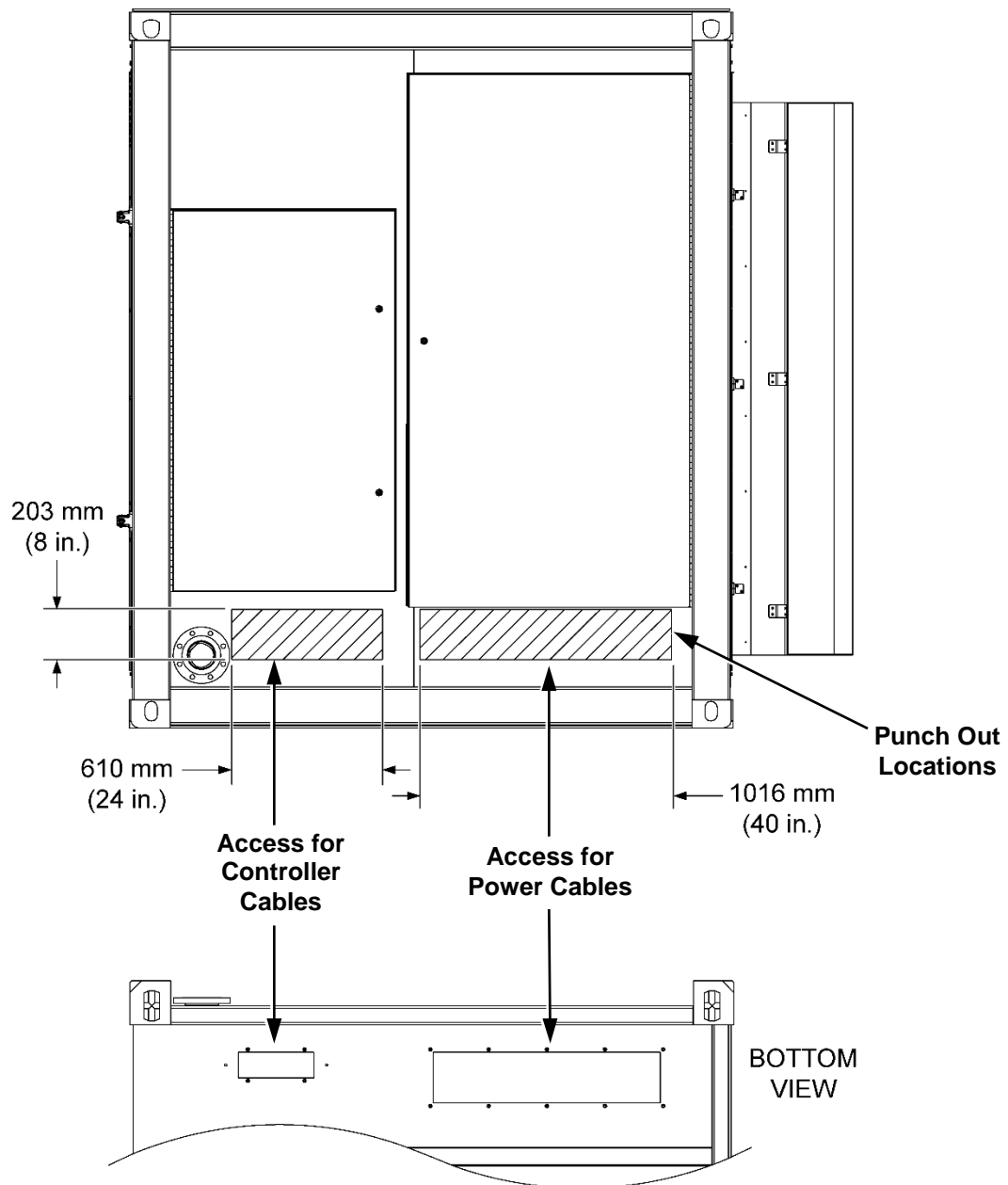
## 4.3. Electrical Connections

### 4.3.1. Electrical Conduit Installation

The access locations for all power and communication cables are shown in Figure 9. This includes the floor access plates and side panel punch out locations. Punch holes in the side panel as necessary only in the dimensions shown, and install water-tight conduit fittings in the punched holes.

Before installing conduit fittings in an access plate, remove the access plate by removing the bolts. Punch holes in each plate as necessary, and install water-tight conduit fittings in the punched holes. The plates are secured by Class 8.8, M8 X 1.25 X 25 bolts at the factory. When installing the access plate, torque each bolt to 25.5 Nm (18.8 ft-lb). If the factory-installed bolt must be replaced, make sure the replacement fastener is corrosion resistant, zinc-plated steel with M8 X 1.25 pitch thread size.





**Figure 9. Cable Access Locations**

### 4.3.2. High Power Connections



## NOTE

Each phase bus bar provides four spaces on two lugs for power cable connection per phase. If an installation requires more than four conductors per phase, the installer can add additional lugs to each bus bar.

See Figure 5 for power cable connection locations on the C1000S/C800S/C600S microturbine. Refer to Table 4 for N-L1-L2-L3 power cable specifications and Table 5 for PE chassis ground cable specifications.

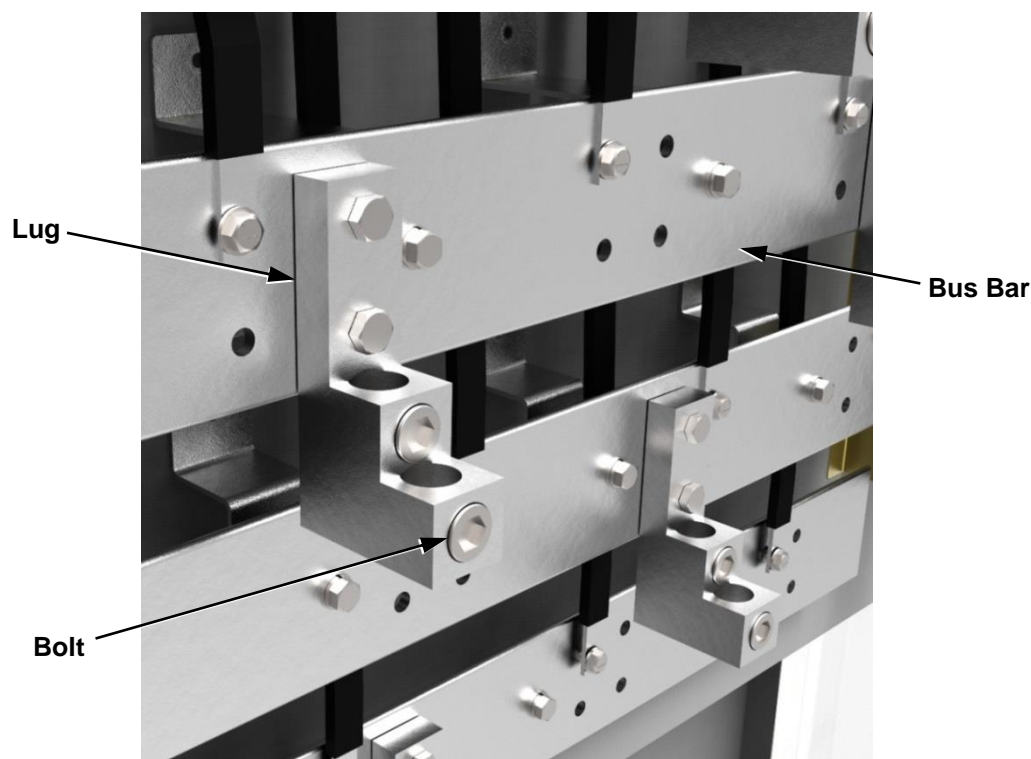


Figure 10. High Power Bus Bar Lugs

Table 4. N – L1 – L2 – L3 Lug Specifications

Maximum Wire Size		Torque Spec per UL486		Conductor Type	Hex Size
MCM	mm <sup>2</sup>	in-lb	Nm		
600	300	500	56.5	Copper or Aluminum	13 mm (0.5 inch)

Table 5. Ground Bar Specifications

Maximum Wire Size		Torque Spec per UL486		Conductor Type	Hole Size
MCM	mm <sup>2</sup>	in-lb	Nm		
600	300	500	56.5	Copper	11 mm (0.44 inch)

Power connections are made using sets of 600 MCM cable (three phases plus neutral) as listed in Table 6. The use of multiple 600 MCM cables allows bend radius to be reduced to 14 inches.

**Table 6. Power Cable Sets**

Turbine	Main Power Connection	Maximum Output Current
C600	3 sets 600 MCM	900 A <sub>RMS</sub>
C800	4 sets 600 MCM	1200 A <sub>RMS</sub>
C1000	4 or 5* sets 600 MCM	1500 A <sub>RMS</sub>

\* Fifth lug would need to be added.

### 4.3.3. Heater Power Connections

In a high humidity configuration, power for the heaters installed in the microturbine bays must be externally supplied. Refer to Table 7 for heater power connection requirements. See Figure 11 for the heater power distribution block in the EPDB.

**Table 7. Heater Power Connections**

Parameter	Specifications		
Input Voltage	110 to 240 VAC, 50/60 Hz		
Terminal Block	Feed-through modular terminal block, spring cage connection, 5.2 mm width		
Wire Specification: Wire Size/ Cross Section	110 VAC: 110 VAC: 8 AWG/10 mm <sup>2</sup> 240 VAC: 12 AWG/4 mm <sup>2</sup>		
Current Consumption:	<b>C1000S</b>	<b>C800S</b>	<b>C600S</b>
110 VAC	40 A	33 A	26 A
240 VAC	18 A	15 A	12 A

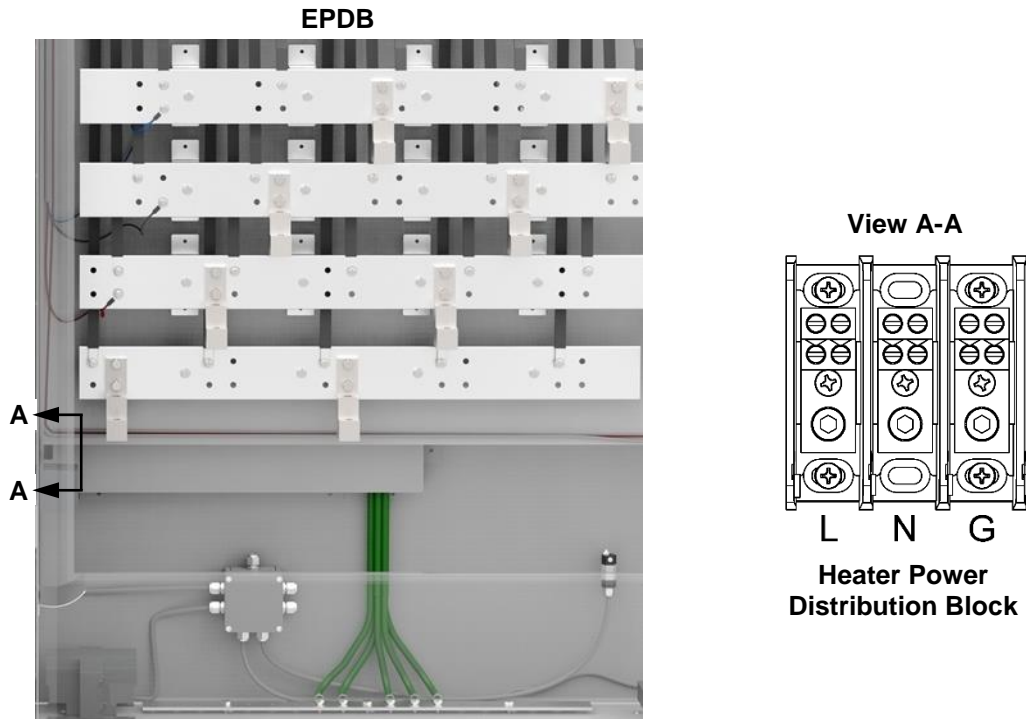


Figure 11. Heater Power Connections

#### 4.3.4. Controller Customer Connections

Make controller wire and Ethernet cable connections to the components shown in Figure 12. Terminal block connections and specifications are shown in Figure 13 and Table 8. Refer to Section 8 for wiring diagrams. Refer to the C1000S/C800S/C600S Technical Reference (Table 1) for a detailed description of all controller wiring.

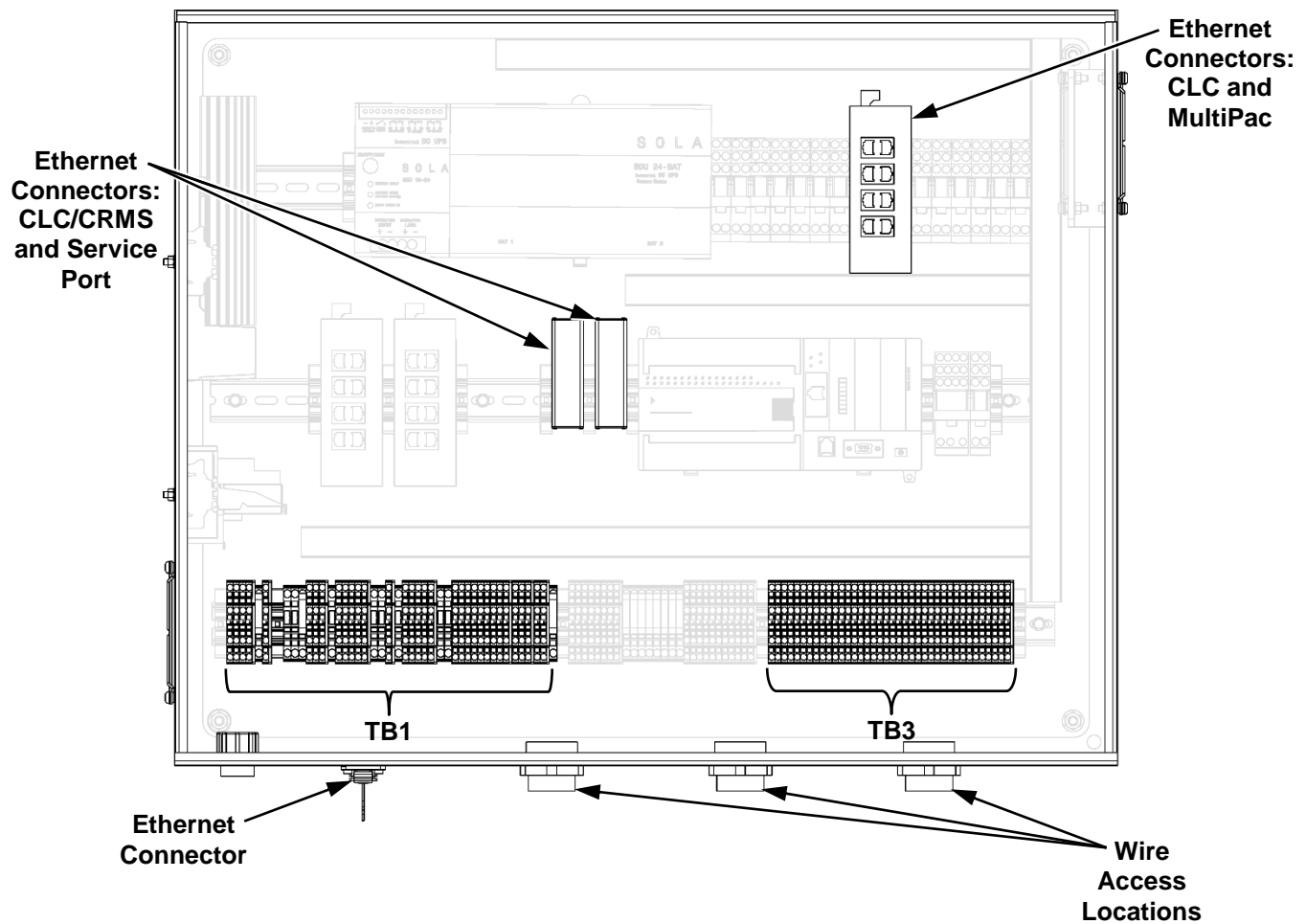


Figure 12. C1000 Series Controller Connections

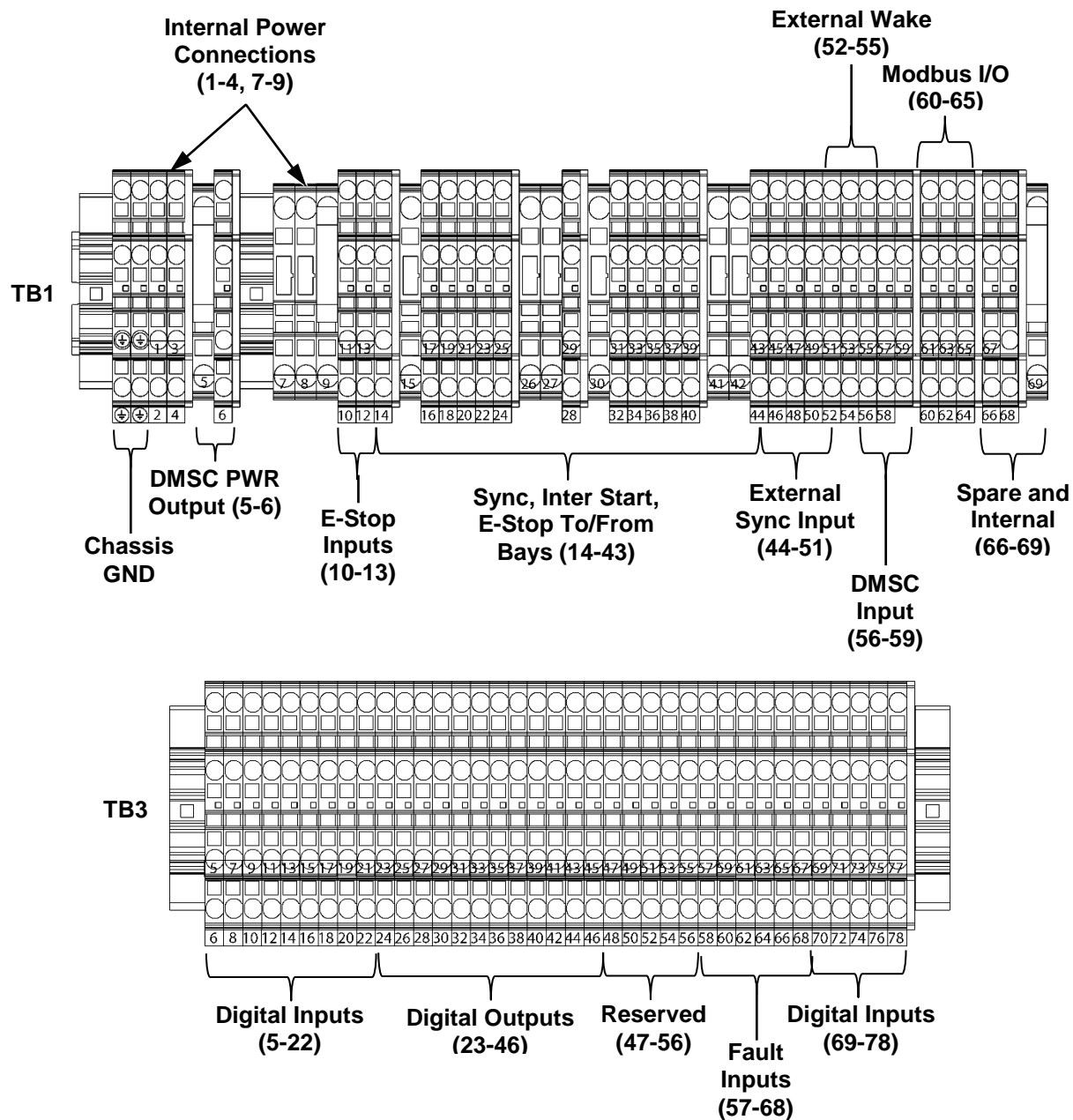


Figure 13. C1000 Series Controller Terminal Blocks for External Connections

Table 8. Terminal Block Wire Specifications

Terminal Block Type (Figure 13)	Conductor Cross Section	AWG	Stripping Length
Double Level	0.08 to 4 mm <sup>2</sup>	28 to 12	8 to 10 mm
Single Disconnect	0.08 to 6 mm <sup>2</sup>	28 to 10	8 to 10 mm

## 5. Mechanical Installation

Mechanical installation involves proper site location with regard to ventilation, mounting, service clearances, ducting, piping, and ambient temperature and humidity. Items to consider include:

- Warranty and FPP policies for removal or replacement have been calculated based on the service areas specified on the O&I drawings. When those areas are violated, the customer, even under warranty, may be required to pay for the additional time required to service the system.
- Service clearances specified in the C1000S, C800S, or C600S O&I Drawing (Table 1) do not account for equipment maneuverability to and from the service area.
- Special equipment (engine removal tool, forklift, etc.) may be needed for large component removal — engine, GCM, LCM, and battery packs, for example — adequate room for the equipment and personnel to lift the equipment out is required.
- Provide doorway and passageway access — width and height — sufficient to allow movement of components and service equipment. Access requirements in mechanical codes are dependent upon equipment type, size, and power.
- Provide sufficient working space around electrical equipment, as defined by applicable codes.
- Allow enough room for socket wrenches on all external panel fasteners — room for power drivers is preferred. This is especially important when the corners of the enclosure are in close proximity to other units or heat exchangers or walls or support structure.
- Always consider fuel and water lines, pipe supports, conduit runs, and any other structural items that may interfere with door access or service clearances. These items, especially pipe supports for exhaust ducting, tend to be the last installed and can easily be overlooked when establishing service clearances around the microturbine.
- Surface temperature of the microturbine exterior, especially the upper external surfaces and exhaust pipe. Allow sufficient clearance to avoid injury to personnel or damage to other equipment.
- The rear of the microturbine should be easily accessible with a fork lift or engine removal tool to allow engine removal during overhauls.

## 5.1. Mounting



### NOTE

Foundation design is the responsibility of the distributor and/or end user. Check the local building codes for load bearing capacity requirements.

### 5.1.1. Foundation

The microturbine must be mounted on a foundation that will provide the best support, protection, and service access. Foundation considerations include:

- The foundation must support the total weight of the system, which includes the microturbine, accessories, piping, cables, ventilation, and support structures.
- The foundation must also support the weight of any service personnel, service equipment, and microturbine components that are removed or replaced during maintenance and repair. Refer to Table 9 for component weights.
- The foundation must provide enough space for service and repair of the microturbine.
- The foundation must have proper drainage to protect the unit against moisture that can occur from seepage.
- The foundation must address wind loading and seismic requirements.

Place the system on a firm level surface that has no more than a two per cent ( $\leq 2\%$ ) grade, and sufficient drainage to prevent standing water. A concrete foundation with anchored mounting bolts is recommended. The concrete foundation must be built to specified overall flatness and levelness value of FF50/FL33 and local minimum value of FF25/FL17. Refer to American Concrete Institute (ACI) specification 302 for further details. Design the foundation to support a minimum 276 kPag (40 psig) of force.

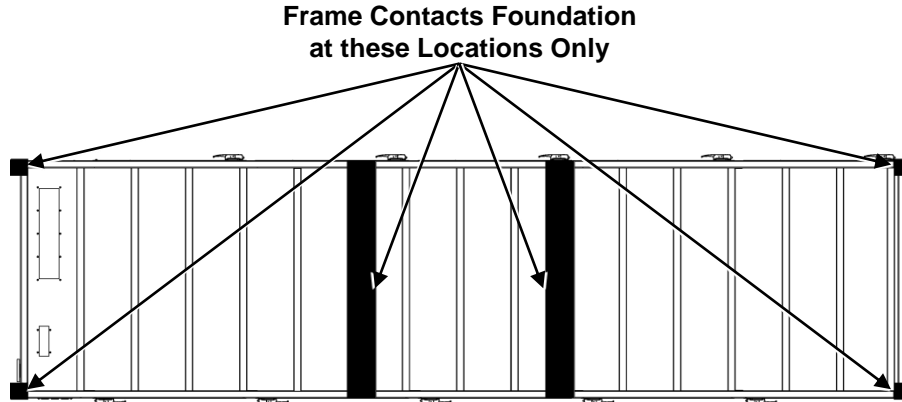
**Table 9. Microturbine Component Weights**

Component	Weight
Microturbine Engine Module (MEM)	670 kg (1478 lb)
Generator Control Module (GCM)	143 kg (316 lb)
Load Control Module (LCM)	214 kg (471 lb)
System Control Module (SCM)	20 kg (44 lb)
Battery Control Module (BCM)	48 kg (106 lb)
Battery	309 kg (681 lb)
Low Pressure Natural Gas (LPNG) Module	275 kg (606 lb)
Liquid Fuel (LF) Module	
Inlet Hood	80 kg (176 lb)
C1000 Series Controller	60 kg (132 lb)



### 5.1.2. Mounting the Microturbine

The C1000S/C800S/C600S frame must contact the foundation only at locations shown in Figure 14. Use the ISO 1161 corner castings to secure the frame to the foundation. Refer to the C1000S, C800S, or C600S O&I Drawing (Table 1) for details.



**Figure 14. C1000S/C800S/C600S Frame Contact Locations (Bottom View)**



Mounting considerations include:

- Forklift slot access.
- If installed outdoors, do not alter the enclosure or remove exterior fasteners because rain will be able to enter the enclosure.
- If installing accessories such as a heat recovery module to an outdoor unit, use properly rated sealant or fittings to keep water out of the enclosure.
- Vibration isolators are generally not required, as vibration transmission from the microturbine to surrounding equipment is minimal.
- If ground settling or earthquakes are possible, provisions should be made to relieve stresses at all connection points — for example, electrical connections, fuel connections, intake air ducting, and exhaust ducting.
- When installed in high H<sub>2</sub>S environments, additional drainage may be required to prevent the deposit of H<sub>2</sub>S on the microturbine enclosure.

## 5.2. Orientation

Orientation is an important element of site design. Items to consider are as follows:

- When installing multiple systems, place microturbines such that the exhausted engine and electronics air does not get ingested into the air intake of a nearby microturbine, as this will de-rate power output. See Figure 15 through Figure 17 for layout examples.

	 <b>WARNING</b>
	<p><b>HOT AREA:</b> When microturbines are oriented per Figure 15, the temperature at the enclosure exhausts between microturbines can exceed 66 °C (150 °F). To prevent injury, when replacing/servicing an engine in one bay, shut down all bays in both enclosures that are oriented in this way.</p>

- Ideally, the inlet will face away from dirty areas — areas containing atmospheric pollutants such as acidic fumes, cement dust, stone dust, cotton fibers, furnace chemicals, etc.
- Microturbines consuming air heated above the local ambient temperature may produce less power due to de-rating.

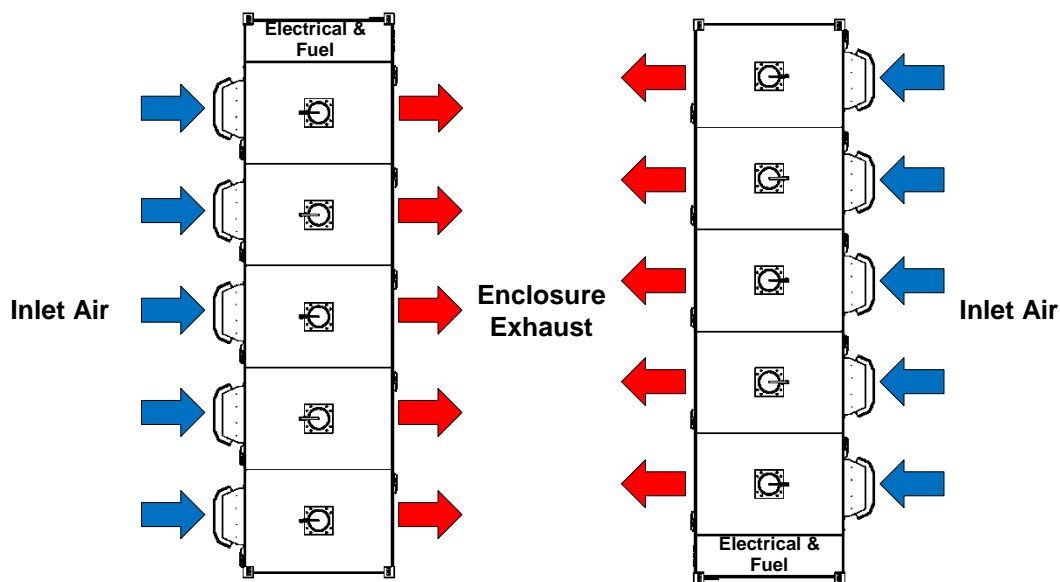


Figure 15. Microturbine Orientation Example #1

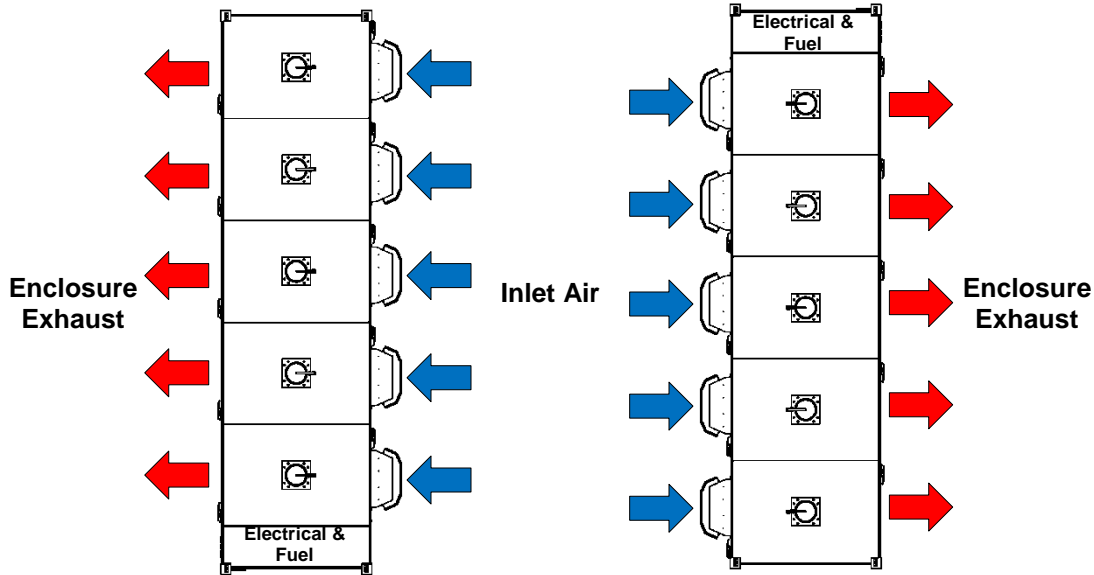


Figure 16. Microturbine Orientation Example #2

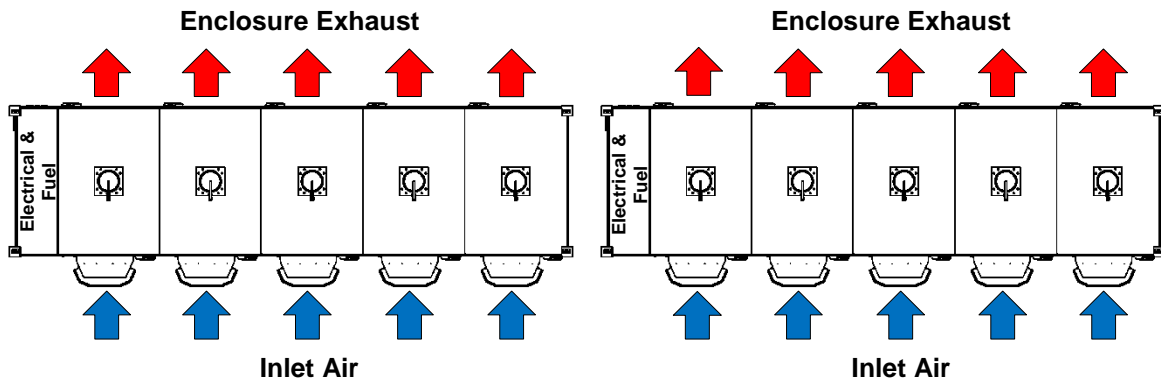


Figure 17. Microturbine Orientation Example #3

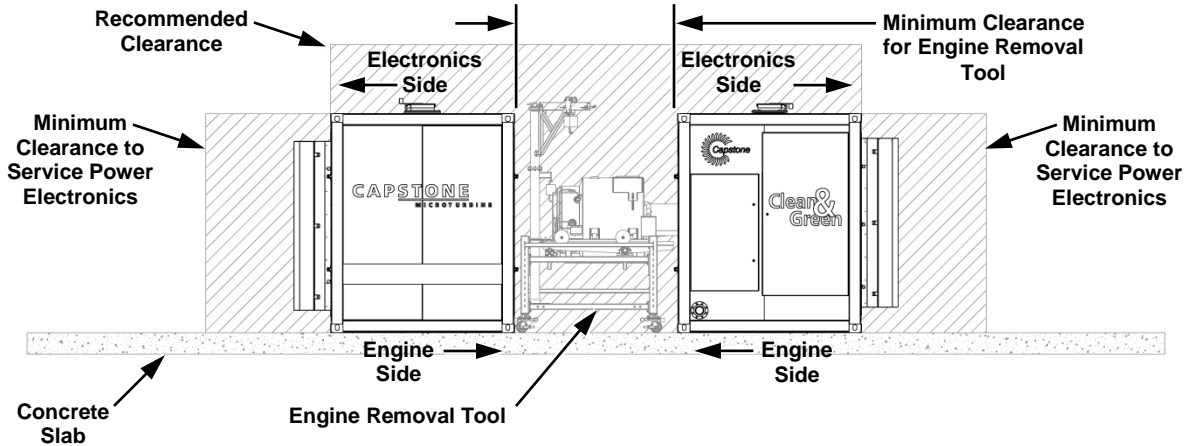
### 5.3. Service Clearances

See Figure 18 through Figure 20 for clearance requirements. Service clearances must allow for maintenance, service, and repair. When designing placement of systems and exterior housings, clearances need to account for the following.

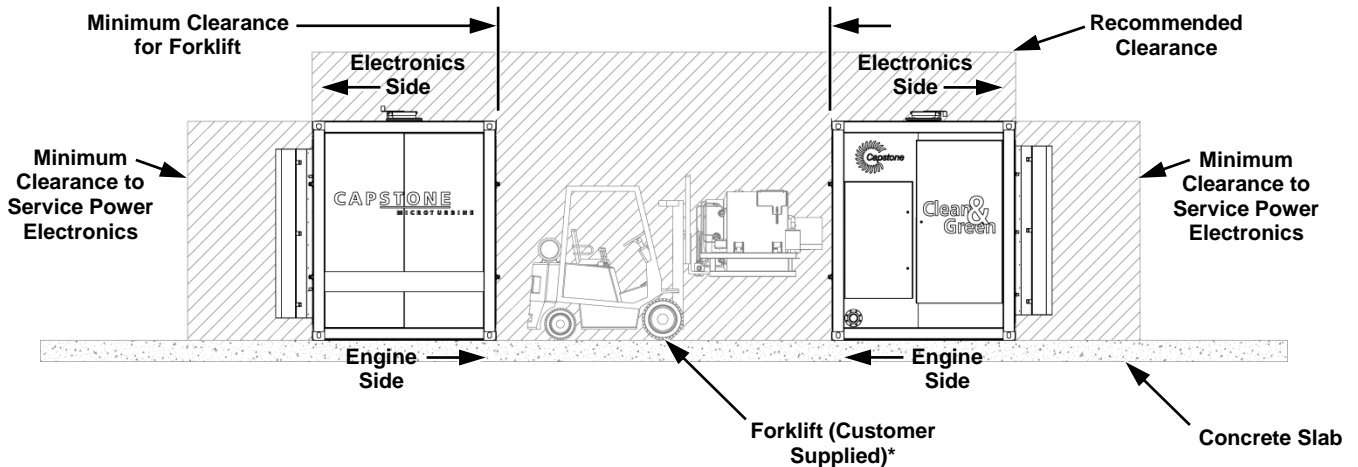
- Space needed to remove various components/modules (for weights refer to Table 9). Refer to C1000S, C800S, or C600S O&I Drawing (Table 1) for actual dimensions.
- Space required for service personnel and equipment such as forklifts. Refer to C1000S Mechanical Coordination Diagram (Table 1) for details.

- Access between any loading area and the enclosure should be clear of obstruction and allow for ease of movement for engines and components. Refer to C1000S Mechanical Coordination Diagram (Table 1) for details.
- Warranty and FPP policies for removal or replacement have been calculated based on the service areas specified on the O&I drawings. When those areas are violated, the customer, even under warranty, may be required to pay for the additional time required to service the system.

#### Engine Removal Tool for Servicing

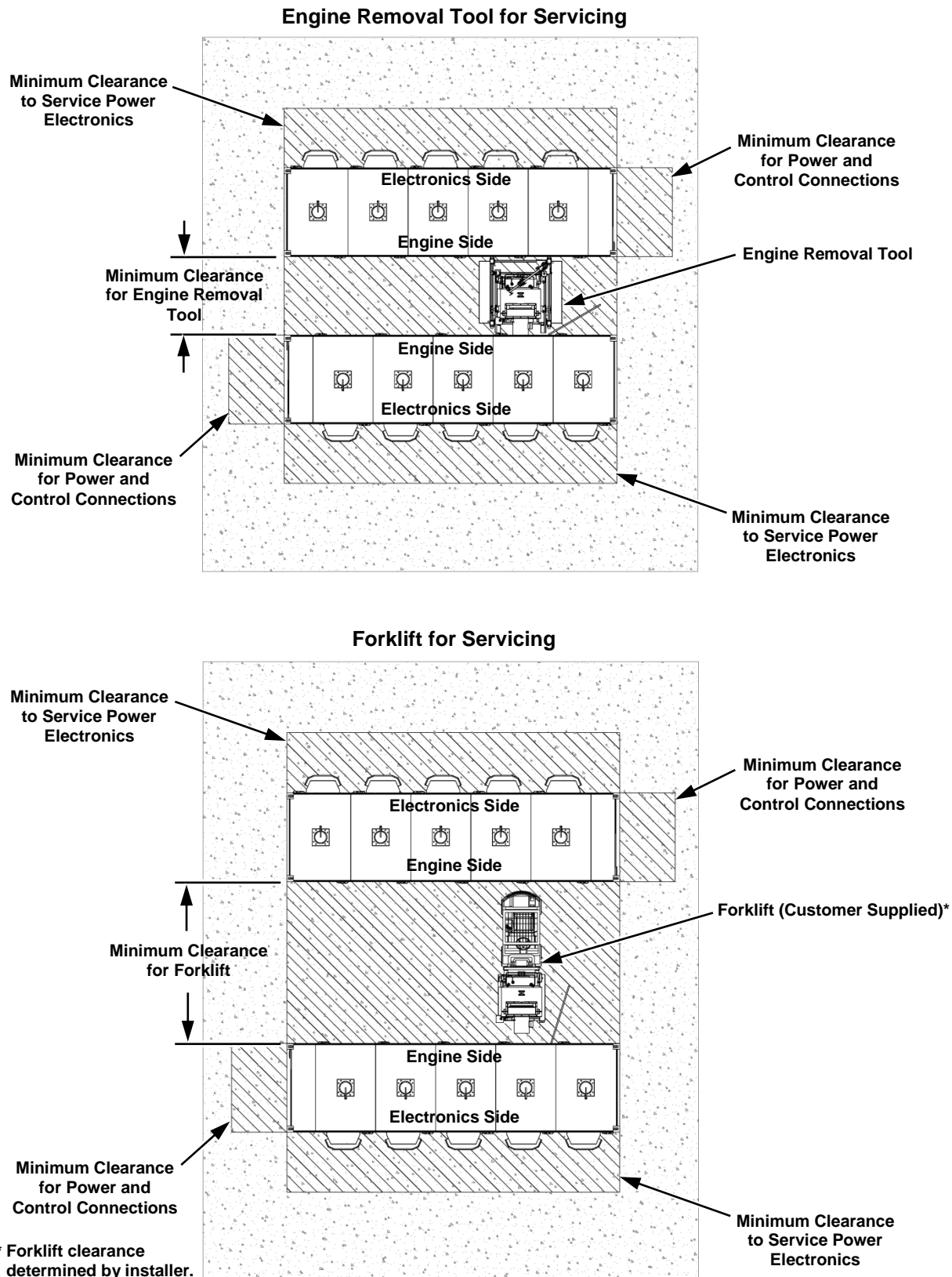


#### Forklift for Servicing



\* Forklift clearance determined by installer.

**Figure 18. C1000S/C800S/C600S Installation Clearances – Side View**



**Figure 19. C1000S/C800S/C600S Installation Clearances – Top View**

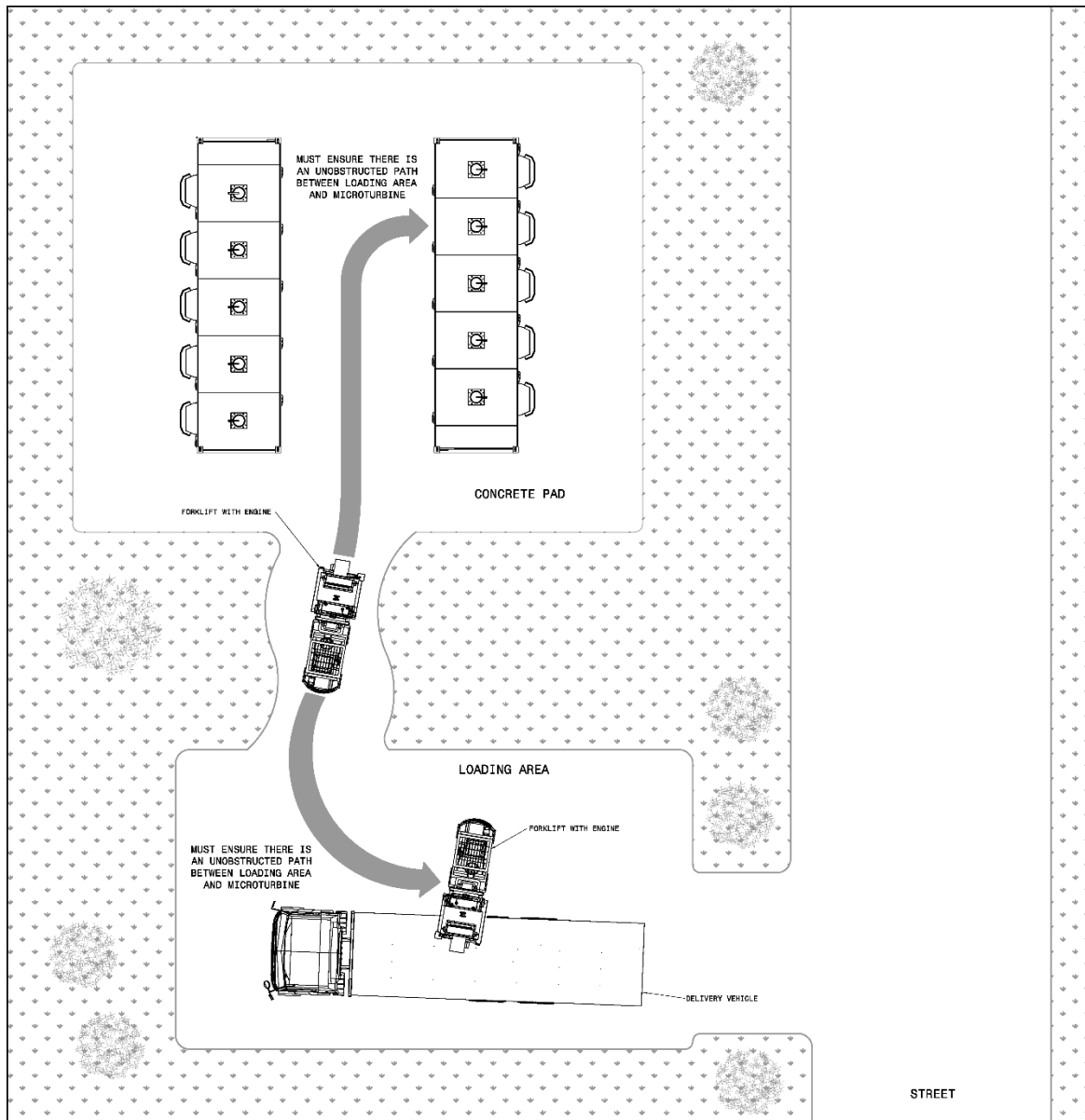


Figure 20. Example Site Path for Engine and Component Delivery

## 5.4. Ventilation

Proper ventilation of the air inlet and exhaust are critical to microturbine performance and longevity. Microturbines require a large amount of air for both engine combustion and enclosure cooling.

Airflow paths are shown in Figure 21. There are two separate air inlets in the C1000S/C800S/C600S microturbine, one for engine combustion air, and one for cooling of internal modules — electronics, fuel skids, etc. The Capstone microturbine exhaust also consists of two components, the combustion air exhaust and the enclosure/electronics exhaust.

### 5.4.1. Ventilation Recommendations

To help ensure proper ventilation, observe the following recommendations:

- Air inlets should be located away from all ancillary equipment heat sources.
- Enclosure/electronics exhaust must be vented to a location where it will not be re-ingested or ingested by other systems.
- Engine exhaust must be vented to a location where it will not be re-ingested or ingested by other systems or present a suffocation hazard to personnel.
- Make provisions for condensation prevention on engine exhaust ducting, including sloping ducting, drip legs, etc., per local mechanical codes.

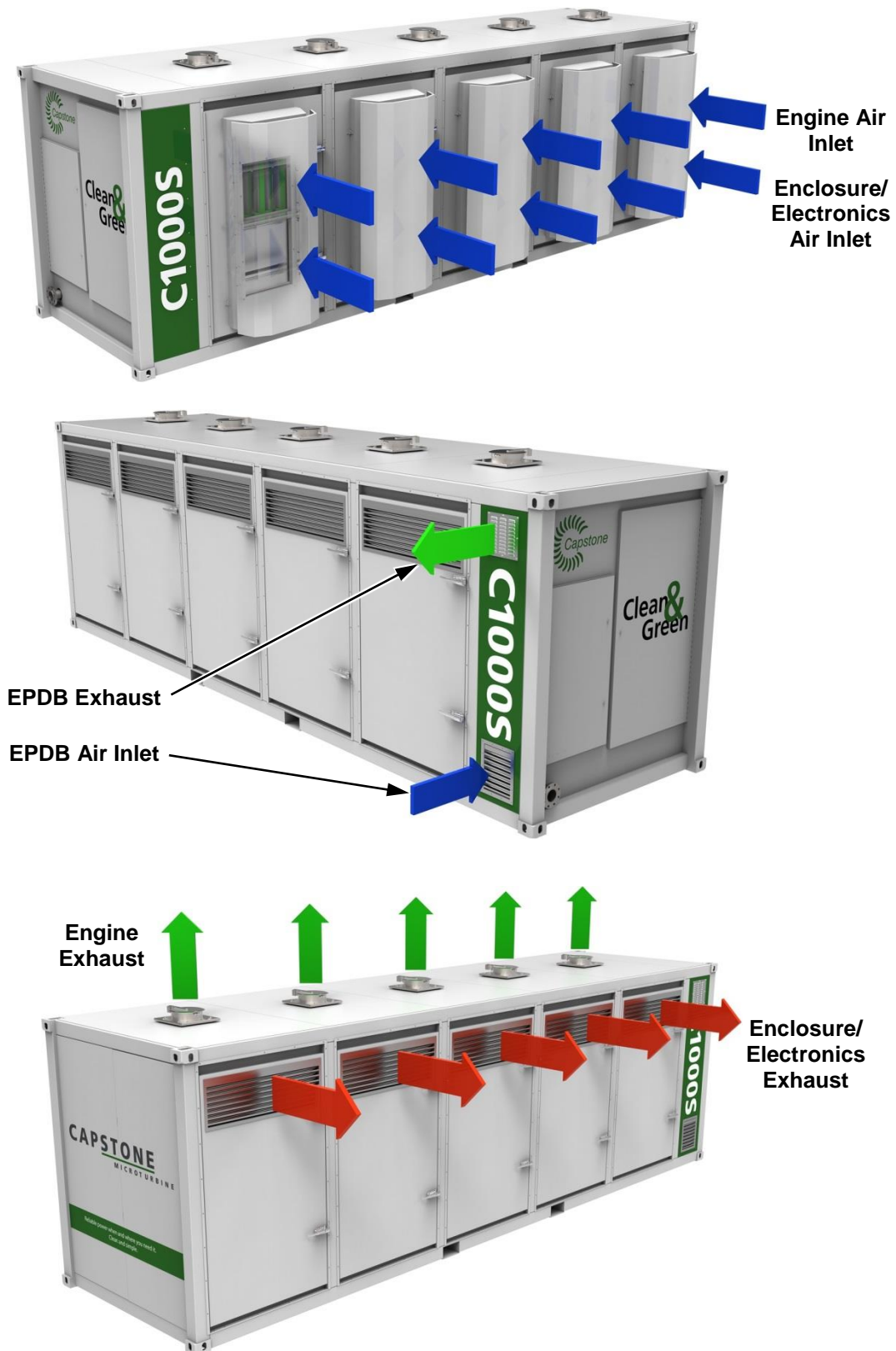
#### 5.4.1.1. Indoor Installations

- The pressure drop within the room should not exceed 249 Pa (1 inch WC) under all operating conditions. Forced ventilation may be required to ensure pressure drop requirements are met.
- Package exhaust vented into a room will increase room temperature, which will derate the microturbine and reduce the cooling of the electronics. Extraction fans with thermostat controls can be used to remove enclosure/electronics exhaust.
- Ventilation should eliminate hot air dead spots, where air movement is not uniform.
- Insulating the engine exhaust ducts decreases heat transfer to the room air hence decreasing the ambient room air temperature.
- The impact of exhaust ducting on backpressure must also be considered. If the distance is greater or the duct size is different, backpressure at the microturbine exhaust can increase, thus reducing the allowable backpressure available for ducting after the HRM.
- Adequate lighting should be provided for proper operation and maintenance of the equipment.



## NOTE

For indoor installations, cabinet exhaust can be modified for upward exhaust. Contact Capstone Applications for details.



**Figure 21. Airflow Paths for a C1000S/C800S/C600S Microturbine**



#### 5.4.1.2. Outdoor Installations

- Install the microturbine in a manner such that prevailing winds will carry engine exhaust away from the air intake. See Figure 22.
- The microturbine should be located away from polluted atmosphere acidic fumes, digester contaminated air, all forms of dust (e.g. cement dust, stone dust, etc.), cotton fibers, furnace chemicals, etc., whenever possible.
- It is recommended that a wall be constructed to protect the microturbine from wind-borne contaminants.

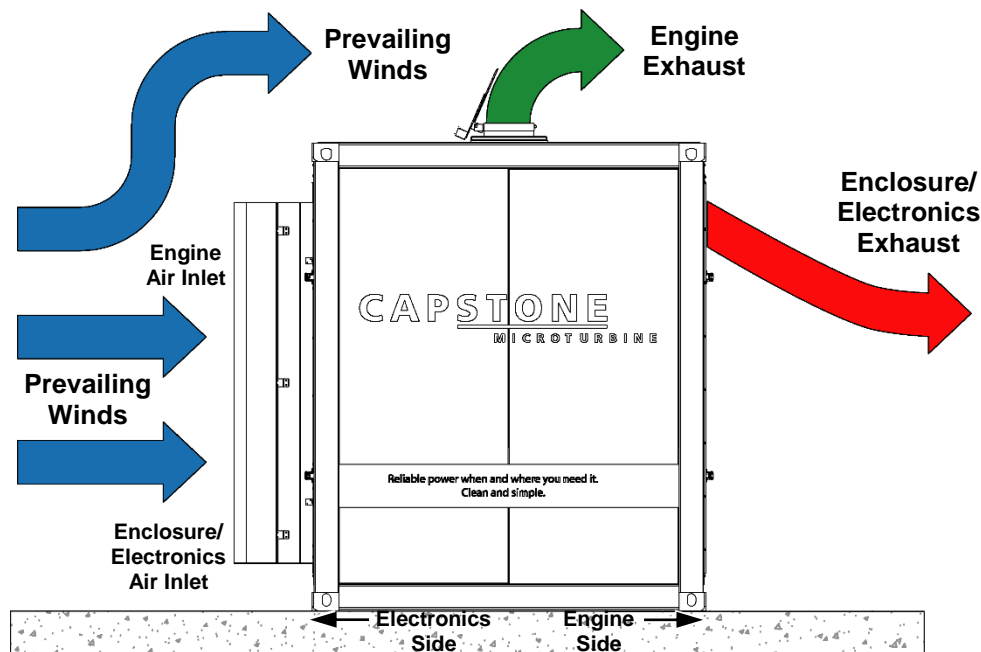


Figure 22. Orientation to Prevailing Winds

#### 5.4.1.3. Extreme Cold Environment Installations

For extreme cold applications (less than 20 °C/-4 °F), unit(s) must be installed in a closed room and adhere to recommendations listed in Indoor Installations (paragraph 5.4.1.1).

- To maintain proper room temperature, install temperature-controlled louvers.
- Room heating may be needed to maintain the required inlet temperature limits.
- Black-start considerations: Microturbines may experience cold soak in temperatures below the low limit. Catalytic heaters can use the pressurized microturbine fuel to heat the room and microturbine before the engine starts.
- Consider installing a separation wall with louvered or removable sections to allow recirculation of hot air to the inlet side of the microturbine when ambient temperatures are colder in the microturbine room.


### 5.4.2. Air Inlet

Airflow requirements for each model are listed in Table 10. Airflow requirements are the same for all C1000S/C800S/C600S configurations, including low pressure and dual mode versions with batteries.

**Table 10. Air Flow Requirements at ISO Conditions with Zero Backpressure**

Microturbine Model	Airflow Requirements
C600S	18,600 scfm (526,800 slpm)
C800S	24,800 scfm (702,400 slpm)
C1000S	31,000 scfm (878,000 slpm)

In the process of producing power, the internal components — electronics, gas compressors, etc. — produce heat. This heat must be removed by the enclosure cooling air supply under all potential operating conditions. Following the inlet air flow rate requirements in the C1000S Product Specification (Table 1) will ensure successful internal cooling through the full range of ambient conditions. Additional information regarding allowable pressure drops and their effect on microturbine performance can be found in the C1000S/C800S/C600S Technical Reference (Table 1).

	<b>CAUTION</b>
	<p>Too much inlet pressure drop can result in engine damage when installed indoors or within a third party enclosure. The maximum allowable inlet pressure differential to the microturbine enclosure is 249 Pa (1 inch WC) with reference to outdoor ambient pressure.</p>

### 5.4.3. Enclosure/Electronics Exhaust

Enclosure/electronics exhaust can exit the microturbine enclosure at temperatures greater than 38 °C (100 °F). The microturbine must have enough ventilation to accommodate the heat rejection levels shown in Table 11. Care should be taken around the enclosure exhaust, especially for indoor installations. When installed outdoors, the microturbine enclosure exhaust is typically trivial when proper installation guidelines are followed.

**Table 11. Heat Rejection per Microturbine Model**


Microturbine Model	Heat Rejection
C600S	135 kW (460,600 BTU/hr)
C800S	180 kW (614,200 BTU/hr)
C1000S	225 kW (767,700 BTU/hr)

### 5.4.4. Engine Exhaust

The engine exhaust system consists of a single pipe exiting the recuperator and vented through the top of the enclosure. The exhaust ducting should be rated up to 371 °C (700 °F). Proper care should be taken in the disposal of this heat, whether that disposal is in the form of heat recovery or exhaust to the ambient air. The main objective is to transfer the hot exhaust to an acceptable area with minimal pressure drop or flow restriction.

The exhaust flow published in the C1000S Product Specification (Table 1) is presented in "standard" CFM, so must be corrected for temperature and pressure where applicable. Corrected flow CFM must be used for duct sizing and backpressure calculations. Please contact your local Capstone Turbine authorized distributor for assistance with an "actual" basis estimate for your conditions.

#### 5.4.4.1. Exhaust Backpressure

	<b>CAUTION</b>
	Too much exhaust backpressure can result in engine damage. The maximum allowable exhaust backpressure is 1245 Pa (5 in WC) for the low emissions model and 1990 Pa (8 in. WC) for all other models, when measured prior to any exhaust ducting/devices, heat exchanger, or CO reduction catalyst.

The total backpressure generated by all connected equipment and exhaust ducting downstream of the microturbine exhaust outlet cannot exceed the maximum allowable backpressure of 1245 Pa (5 in WC) for the low emissions model and 1990 Pa (8 in. WC) for all other models. Backpressure will impact engine performance, which is detailed in the Performance chapter of the C1000S/C800S/C600S Technical Reference (Table 1). The maximum allowable backpressure may be reduced by configuration. Refer to the C1000S Product Specification (Table 1) for specific backpressure limitations.

#### 5.4.4.2. Exhaust Ducting Considerations

Duct diameter and length must be designed such that backpressure at the microturbine is less than that specified in the C1000S Product Specification (Table 1). Ducting needs to be supported and designed to allow for servicing of the microturbine. The duct cannot be welded to the engine or upper stack.


Allow for condensation drainage. The combustion process generates water as a byproduct. Additionally, it is possible for the exhaust to condense — or continue to condense — especially after a heat exchanger. It may be necessary to install drain ports in long exhaust ducting runs to remove condensate so that it does not collect and run back towards the microturbine. It may also be necessary to slope the exhaust ducting.

At full power, microturbine nominal exhaust temperatures can exceed 316 °C (600 °F). Temperatures can be higher due to fuel contamination. It is recommended that exhaust ducting be rated for 371 °C (700 °F).

Make sure that thermal insulation is sufficient to avoid hazards to personnel or buildings due to contact with high temperature exhaust ducting. Double-wall stainless steel ducting with two-to-four (2-4) inch ceramic fiber insulation is a general purpose solution. Specifics of the application must be considered when designing a proper installation.

Make sure that exhaust stack material and thickness meets local codes. As a "medium heat" device, be aware of requirements regarding penetration through roofs and walls of combustible and non-combustible material. If these penetrations are designed and stamped by an engineer, building departments are usually satisfied, allowing wall penetrations in multistory buildings. Double-walled chimneys may be required.


#### 5.4.4.3. High H<sub>2</sub>S Installations

	<b>CAUTION</b>
	For high H <sub>2</sub> S Installations, common exhaust connection is prohibited due to the risk of corrosive, sulfuric-acid-containing, condensation draining back into non-operational microturbines. This corrosive condensation can damage equipment in the microturbine and would not be covered by warranty.

The combustion of H<sub>2</sub>S creates sulfur oxide compounds which can combine with water to create sulfuric acid. For this reason, all exhaust ducting and any heat recovery equipment must be stainless steel. Increase the height of the exhaust stack to 10 feet minimum to improve dilution of the sulfur oxides.

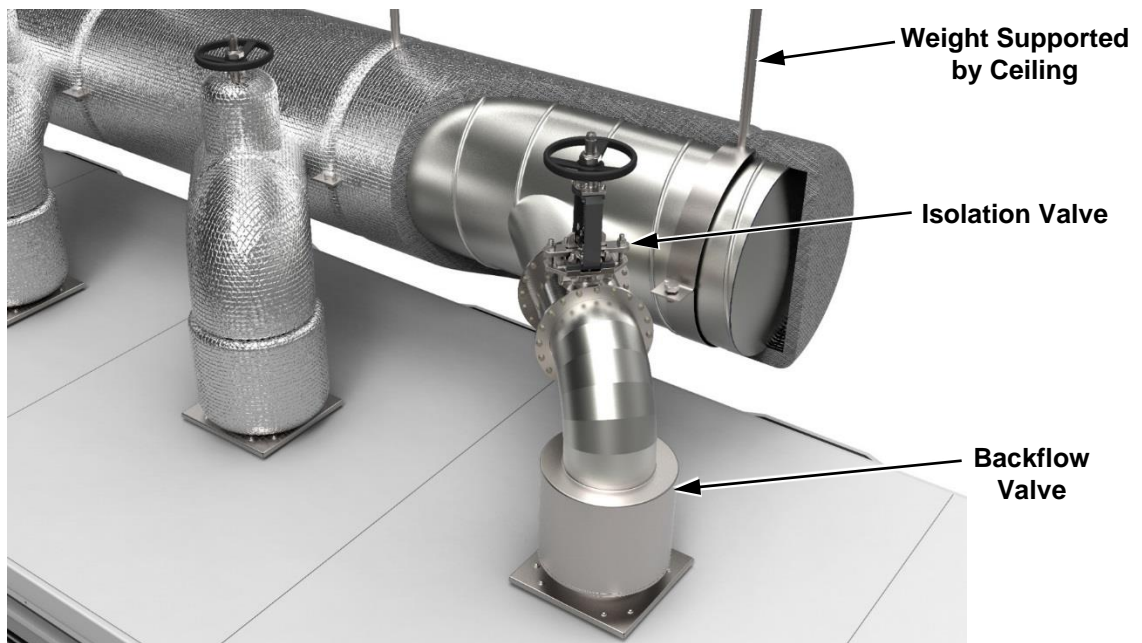
The use of condensate drains is required and they must be located such that all condensates are prevented from collecting in the recuperator.

#### 5.4.5. Common Exhaust Ducting

	<b>CAUTION</b>
	Stagger the entry points into a common exhaust header so that individual microturbines are not directly opposite one another. Differences in exhaust flow may create backpressure on a turbine and limit its performance or cause damage.

See Figure 23 for an example installation using common exhaust ducting. Ducting the engine exhaust of multiple microturbine bays requires the use of a backflow valve for each bay's exhaust duct. If there are no backflow valves installed, a wiring interlock mechanism must be installed between bays to stop the operation of all systems if any individual ceases operation.

Silencers or baffles may be used, but pressure drop and temperature rise must be considered. Pressure should be checked by placing a pressure sensor in a sampling port in the exhaust pipe above the microturbine. Measure actual pressure to make sure that it is below the specified maximum.

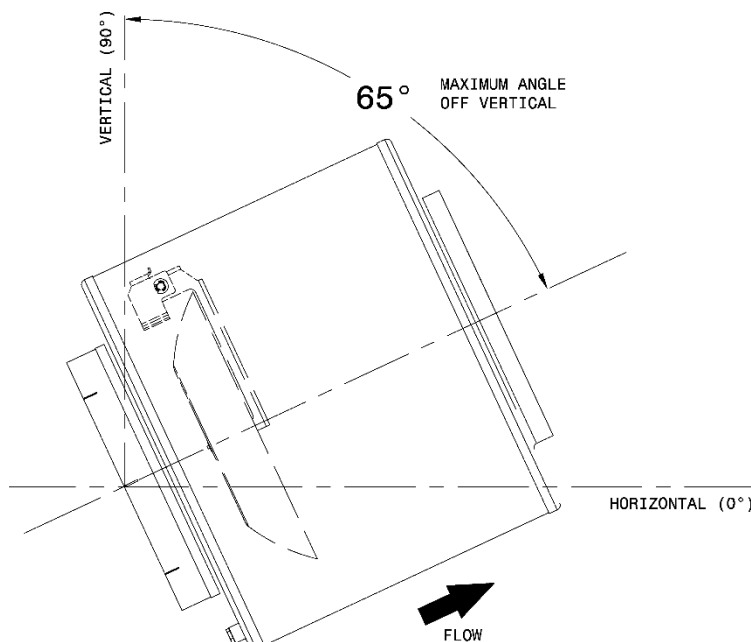


**Figure 23. Ducting Installation Example**

#### **5.4.5.1. Capstone Backflow Valve Installation**

When installing a backflow valve, ensure the following:

- If installing the Capstone backflow valve in ducting that is not vertical (90°), the angle of the damper must not be less than 25° above horizontal, as shown in Figure 24.
- Make sure that the flapper hinge is installed at top dead center.
- The flapper must form a good seal without binding.
- Install a service port near the backflow valve for visual inspection.



**Figure 24. Backflow Valve Requirements**

	CAUTION
	<p>If an automatic isolation valve (separate from Capstone's backflow valve) is installed, the customer must provide a level 4 fault input from the valve to the UCB as described in Section 8.3.4. This is to ensure that the microturbine will immediately shut down, or not start, if the automatic valve is closed. Failure to do so can cause severe damage to the microturbine.</p>

#### 5.4.5.2. Isolation Valve/Blanking Plate

	CAUTION
	<p>When using an isolation valve or blind plate to isolate microturbine exhaust, the microturbine must be locked out with a clear instruction that the isolation valve be opened before the lockout is removed. If an engine start is attempted with a closed valve, the bearings will fail immediately. This damage is not covered by warranty.</p>

	CAUTION
	<p>Since Capstone backflow valves do not provide a bubble-tight seal, installations sharing a common exhaust duct will allow a small amount of hot exhaust leakage into non-operating units. The water content in this exhaust leakage may condense in the non-operating engine recuperator and power head, potentially causing damage to the engine.</p>

For periods of non-operation longer than 48 hours, 100% isolation is required using a blanking plate, gate valve, etc. between the common exhaust header and the backflow valve (see Figure 23).

The preferred means of isolation is to install a gate or butterfly valve to isolate individual exhaust ducts from the common header. Gate valves can provide a zero leakage seal and be operated while the other turbines are running.

An acceptable means of isolation is to include a flanged joint in the exhaust duct as a location to install a blind plate during long term non-operation. Blinding operations cannot be performed while exhaust duct is still hot. Be aware that heat from operational turbines may limit the ability to install blind during operation.

## 6. Fuel Delivery (Pipeline Natural Gas)

Capstone systems are generally designated by the type of fuel on which they are intended to operate. Examples of approved fuels include pipeline quality natural gas, raw natural gas, biogas, liquefied petroleum gas (LPG), and liquid fuels. Refer to Section 4.1 for fuel connection type, thread details, and pressure requirements. Fuel quality requirements for Capstone microturbines are provided in the Capstone MicroTurbine Fuel Requirements Technical Reference (Table 1).

Reliability of microturbine operation is based on the quality of the gas at the microturbine inlet. This leaves the business partner and/or end-user responsible for the following:

- Assessing the need for gas cleanup and conditioning
- Selecting, installing, operating, and maintaining the appropriate gas cleanup and conditioning equipment

### 6.1. Fuel Conditioning System

This section describes the components involved in a pipeline quality natural gas fuel conditioning system. Other fuels have different requirements which are described in that fuel's application guide (Table 1).

Capstone is not responsible for the design, installation, or operation of fuel conditioning and delivery systems. Proper maintenance of fuel delivery systems is necessary for normal microturbine performance and routine maintenance intervals. Capstone recommends engaging appropriately skilled personnel for the design and installation of fuel conditioning and delivery systems as these can be particularly technically challenging applications.

Examples of pipeline natural gas installations are shown in Figure 25. Components outlined in red are required for each microturbine in an installation. Components outlined in green vary by application, local regulatory code, and site requirements. A filter at each unit allows for targeted troubleshooting of condensation or piping problems. A regulator at each unit eliminates the possibility of fuel pressure fluctuations and nuisance flameouts.



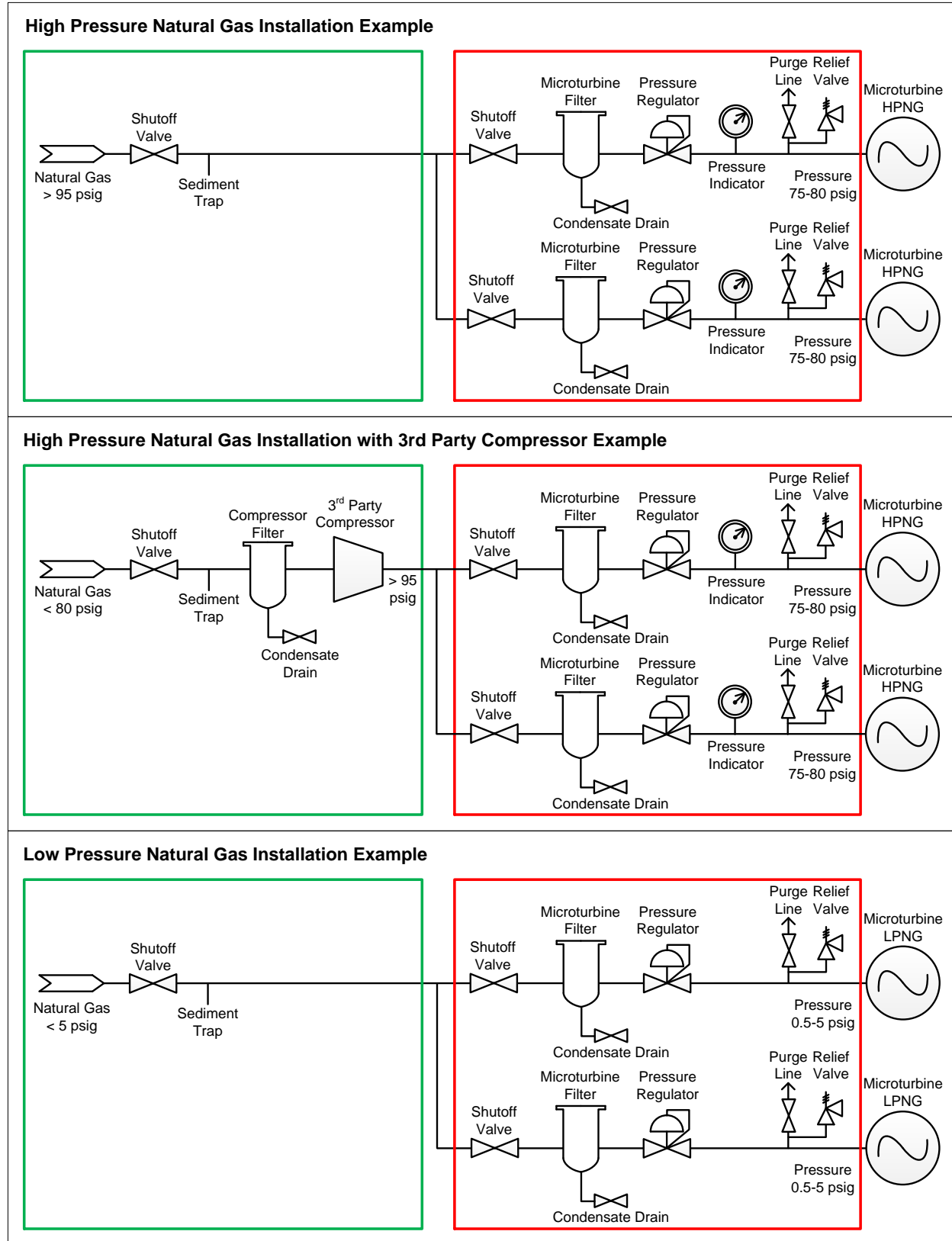


Figure 25. Pipeline Natural Gas Installation Examples

### **6.1.1. Shutoff Valve**

An inlet shutoff valve is installed to lock out the fuel delivery system and microturbine from the fuel source. This can be any type of valve that provides a vapor tight seal and that is compatible with the fuel components. In some cases, this may be an automated valve, which will fail closed in the event of a system shutdown or failure.

### **6.1.2. Sediment Trap**

Capstone recommends that a sediment trap or filter be placed at the beginning of the fuel conditioning system. This filter will eliminate any large particles or contaminants from the site's pretreatment system and piping. Make sure to provide for adequate drainage and disposal of any condensate and sediments or solids captured by this trap.

### **6.1.3. Compressor Filter**

If a flame arrestor or compressor is installed, it may be necessary to install an inlet filter to protect these components from liquid-borne debris. Common filter types include coalescing, mesh-pad, cyclonic, or baffled separators. Take care to select the appropriate filter type and size for the application. In many cases, using a coalescing filter may be sufficient to both remove liquid phase condensate and provide additional filtration. Filters that are collecting liquid must be drained into an appropriate condensate removal system. The approach will differ from one site to another, depending on ambient temperatures, fuel type, moisture content, existing fuel treatment, etc.

### **6.1.4. Third Party Compressor**

When sizing a compressor, consider the pressure or suction at the compressor inlet and consider the pressure drop across the system in order to determine the maximum pressure required at the compressor outlet.

For low pressure natural gas (LPNG) systems, Capstone provides an integrated Fuel Gas Booster (FGB). For additional information on the FGB, please refer to the C1000S/C800S/C600S Technical Reference (Table 1).

### **6.1.5. Microturbine Filter**

Particulate and coalescing filtration is required for each microturbine fuel inlet per the Capstone MicroTurbine Fuel Requirements Technical Reference (Table 1), the O&I drawings, and the P&ID drawings.

Filters should be inspected once a week during the first month of operation. If the filter has construction debris, clean or replace the filter. If the filters are wet, then the gas does not meet dew point suppression requirements. If this occurs, immediate corrective action must be taken, as this impacts performance of the microturbine and the warranty may be voided if damage to fuel system components or engine is caused by fuel moisture. Following corrective action, replace filter elements, and continue checking once a week for several weeks to verify that the filters remain dry.

### **6.1.6. Condensate Drain**

A condensate drain is a device for removing liquid and contaminants from the filter. If a condensate drain is not installed, or the drain is not operating properly, oil and/or water will collect, affecting the filter efficiency. Refer to Section 6.5.3 for details.



### 6.1.7. Microturbine Inlet Pressure Regulator

Fuel pressure regulation is required for each microturbine fuel inlet per the Capstone MicroTurbine Fuel Requirements Technical Reference (Table 1), the O&I drawings, and the P&ID drawings. This regulator will improve reliability by reducing the impact of fuel system pressure dynamics on combustion stability.

### 6.1.8. Inlet Pressure Indicator

A pressure gauge, or indicator, at the microturbine fuel inlet provides a visual indication of fuel pressure and stability, which helps in troubleshooting fuel delivery issues.

### 6.1.9. Purge Line



	<div data-bbox="753 625 1045 674"> <b>WARNING</b></div> <p>FLAMMABLE MATERIAL! Natural gas is flammable and explosive. The discharge of any purge line must always be routed to a safe location, as per local codes or regulations. Failure to observe this warning can result in personal injury or equipment damage.</p>
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A purge line is used to remove dirt and particulates from the fuel line during installation or service by allowing a temporary exit path for fuel. This same exit can also be used as a purge or vent connection. The purge line should be installed right at the turbine inlet.

### 6.1.10. Flame Arrestor (Optional)

Installation of a flame arrestor is optional. Selection is dependent on the pipe size, fuel type, and local code requirements. A flame arrestor dealer can help with sizing and selection if it is determined that one is required.

### 6.1.11. Pressure Relief Valve

	<div data-bbox="753 1239 1045 1287"> <b>WARNING</b></div> <p>FLAMMABLE MATERIAL! Natural gas is flammable and explosive. The discharge of any pressure relief valve must always be routed to a safe location, as per local codes or regulations. Failure to observe this warning can result in personal injury or equipment damage.</p>
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A certified pressure relief valve (set to 100 psig) is required near the fuel inlet of any microturbine where the available fuel supply pressure may reach or exceed 1,034 kPag (150 psig) due to existing upstream supply pressure or equipment failure. Fuel inlet pressures in excess of 689 kPag (100 psig) may prevent the microturbine from initiating a start attempt.

## 6.2. Raw Natural Gas

Raw natural gas — also called wellhead gas or associated gas — is a product of oil and gas drilling and can be found at oil wells, gas wells, and condensate wells. The gas is unprocessed and can contain varying concentrations of heavier hydrocarbons, contaminants such as hydrogen sulfide ( $\text{H}_2\text{S}$ ) and chlorides, and diluents such as carbon dioxide ( $\text{CO}_2$ ) and nitrogen.

Special pretreatment consideration must be taken with raw natural gas due to possible high concentration of hydrogen sulfide ( $\text{H}_2\text{S}$ ), water vapor, carbon dioxide ( $\text{CO}_2$ ), heavy hydrocarbons, and other contaminants.

Refer to the Raw Natural Gas Application Guide (Table 1) for information on allowable fuels, properties, requirements, and delivery.

## 6.3. Biogas

Biogas, either digester gas or landfill gas, originates from the anaerobic digestion of organic waste materials. The primary byproducts of this process are methane ( $\text{CH}_4$ ) and carbon dioxide ( $\text{CO}_2$ ), with the solid residues rendered essentially inert.

Special pretreatment consideration must be taken with biogas gas due to possible high concentration of hydrogen sulfide ( $\text{H}_2\text{S}$ ), water vapor, carbon dioxide ( $\text{CO}_2$ ), siloxanes, and other contaminants.

Refer to the Biogas Application Guide (Table 1) for information on allowable fuels, properties, requirements, and delivery.

## 6.4. Liquefied Petroleum Gas (LPG)

Liquefied Petroleum Gas (LPG) is characterized as a mixture of propane, butane, and small quantities of various other hydrocarbons such as propylene and butylene. LPG is transferred and stored as a pressurized liquid. Its boiling point is such that it evaporates easily under ambient temperature and pressure. The composition of LPG determines the dew point, heating value, density, and other fuel properties, as well as the percentage of contaminants.

Special pretreatment consideration must be taken with LPG due to the need to vaporize the liquid fuel into a gaseous state. LPG also has a low dew point relative to other fuels.

Contact your local Capstone Turbine authorized distributor for information on allowable fuels, properties, requirements, and delivery.

Refer to the LPG Application Guide (Table 1) for information on allowable fuels, properties, requirements, and delivery.

## 6.5. General Considerations for Gaseous Fuels

### 6.5.1. Pressure

Fuel pressure requirements apply at the microturbine fuel inlet while the system is running. Pressure should be steady when entering the microturbine. Avoid pressure fluctuation by correctly sizing the piping, regulator, valves, and ancillary equipment of the fuel delivery system.

#### **6.5.1.1. Regulators**

Capstone recommends that a fuel pressure regulator be installed at each microturbine. This is especially important in large installations, where fuel pipe volume after a single, large regulator can lead to significant pressure variation between units. Install the fuel pressure regulator as close to the microturbine inlet as practical. A regulator installed too far away from the microturbine will not adequately control the fuel pressure. The pressure regulator should have sufficient pressure drop and size to compensate for variations at the regulator inlet.

#### **6.5.1.2. Pressure Drop**

When designing a fuel delivery system or sizing a compressor, the pressure drop across the system must be considered. Pressure drop is the amount of pressure lost between the high pressure source and the microturbine inlet. Pressure drop is a function of the length and diameter of the pipe, number of bends in the pipe, and each individual component installed in the piping.

For example, if the minimum allowable pressure to the microturbine is 75 psig and the fuel system has a pressure drop of 20 psi between the compressor outlet and the microturbine inlet, then the compressor outlet must be at least 20 psi above the minimum allowable pressure — at least 95 psig for this example. Adding a pressure gauge at the microturbine inlet can assist in establishing the correct settings.

#### **6.5.2. Dew Point Suppression**

Capstone microturbines require strict dew point suppression, which is the amount of moisture removal needed to protect the microturbine from internal condensation. Cooling of the gas in process piping — usually due to ambient temperatures that are lower than the fuel temperature — and gas compression can cause condensation. The fuel temperature at the microturbine inlet must be a minimum 10 °C (18 °F) above its dew point temperature or 0 °C (32 °F), whichever is higher. Failure to prevent condensation inside the microturbine negatively impacts the life of the unit.

#### **6.5.3. Condensate Removal**

Condensate consists of water and other contaminants and must be disposed of accordingly. Manual or automatic condensate removal techniques can be applied depending on the application. Manual ball valves piped to a condensate drain and collector are low cost, but will require an experienced site operator to be properly utilized. Automatic valves can be actuated based on vessel level switch or timer-based inputs. Items to consider are as follows:

- Water will freeze in condensate drain lines, so heat tracing may be required to prevent clogging of condensate systems in cold environments.
- Drain lines from all condensate producing devices should be directed toward appropriate drainage disposal facilities or equipment.
- All piping must have provision for gravity drainage. If the pipe goes underground or has a low point, the condensate will collect there and must be drained. Each pipe must either slope toward a vessel with a drain or take appropriate measures for condensate drainage.
- Avoid over-pressurizing drainage lines. Condensate drain lines from high-pressure sources should not be tied together with drain lines from low-pressure sources. Ideally, all drain lines should be kept separate.

- During normal operation, vacuum pressures may exist upstream of the compressor which can result in condensate ingestion by the gas compressor. Addition of condensate level switches and a small pump to remove the condensate or an additional container and valves on the drain line to isolate the liquid from the vacuum may prevent condensate ingestion.
- Timer-based drainage systems are common in many applications. Even if a fully-automatic drainage system is in place, all condensate traps on the drain line should have a bypass available for manual draining.
- If an installation will be operated without oversight for any length of time, the drainage system should also include high-level switches as alarms to cease operation of the overall installation in the event that some portion of the drainage system fails.

#### 6.5.4. Low Temperature Concerns

Planning for a proper fuel conditioning system must take into account both the hottest and the coldest ambient temperatures that will be encountered at the site. This planning is critical for installations operating in regions experiencing very cold climates that might otherwise freeze condensate in separation vessels, drip legs, or drain lines.

A clogged condensate removal system may result in passing condensate to downstream components such as compressors or microturbines. Adding seasonally-operated heat tracing to any component with potential for clogging the condensate removal system helps prevent system failure.

An operating microturbine will easily maintain heating of internal fuel system components due to the constant fuel flow. When a microturbine is stopped, the fuel temperature drops, condensing liquid onto pipe walls which can gather at low points and eventually freeze. On restart, there may be a clogged fuel line or stuck fuel control valve. Adding internal heating to the microturbine fuel system may be required in cold environments where ice buildup in fuel system components impacts ability to start.

#### 6.5.5. Hydrogen Sulfide (H<sub>2</sub>S)

Hydrogen sulfide is a common and naturally occurring compound found in oil & gas production. The concentration can vary widely in different fuels. Fuels containing hydrogen sulfide are referred to as “sour”, in reference to the odor of H<sub>2</sub>S at low concentration.

The levels of hydrogen sulfide (H<sub>2</sub>S), carbon dioxide (CO<sub>2</sub>), and gas moisture content in a fuel is specific to site and application and will impact maintenance intervals and the life of installed compressors. Many compressors will use specific oils intended to both lubricate the compressor and provide some degree of protection against corrosion.

Hydrogen sulfide is corrosive to metals and sealing materials, with some materials being more corrosion-resistant than others. Selection of both microturbine model and each component of a fuel conditioning system will be impacted by the level of H<sub>2</sub>S content in the fuel. Capstone microturbines can handle varying amounts of H<sub>2</sub>S, and the specific limits for each product line are described in the C1000S Product Specification (Table 1). Do not use galvanized steel, copper, or brass components if the fuel contains H<sub>2</sub>S.

Corrosion in fuel conditioning system components can shorten equipment lifetimes, reduce reliability, and increase the risk of sending out-of-specification fuel to the microturbine. Similarly, higher-than-allowable hydrogen sulfide levels in the microturbine can cause premature failure of fuel system components, injectors, combustion liners, and, if allowed to progress too long, catastrophic engine failure and fire risk.

Project developers should be aware that any hydrogen sulfide in the fuel will be combusted to form sulfur dioxides in the exhaust, which in many parts of the world are regulated as polluting emissions. Contact your local air quality regulating body for more information.

Hydrogen sulfide is an extremely dangerous gas and toxic to humans even at low concentrations. Special care and training are necessary when dealing with fuels containing hydrogen sulfide.

#### **6.5.6. Heat Tracing**

The fuel conditioning system cannot always be located near the microturbines. For long pipe runs, heat tracing and insulation may be necessary to maintain dew point suppression. Heat tracing is an electric heating cable designed specifically for this purpose. Consider wrapping heat tracing around larger components such as valves, regulators, and filters so that the large thermal capacity of the metal does not cause local cooling of the fuel stream.

Sunlight and ambient air convection can help heat the fuel piping, but this is not a reliable method. Pipe insulation is generally added to minimize heat loss during colder seasons which limits contributions from these sources.

#### **6.5.7. Piping**

Fuel delivery piping should be installed by a trained professional. The piping must be rated for the appropriate pressure and temperature, and the piping material must be compatible with all components found in the fuel.

The following considerations should be taken for all microturbine fuel delivery piping systems. In all cases local piping codes must be followed.

- Make sure all fuel connections are tight, leak free, and protected from physical stress.
- Fuel lines must be routed with no kinks or sharp bends.
- Adequate support and protection must be provided for all piping, per local codes.
- Make sure that the piping supplying the unit is well-protected from foot and equipment traffic.
- Flexible fuel lines may have code restrictions on length, location of service, protection, pressure, fuel type, end fitting type, and material.
- PVC fuel lines may not be allowed depending on local codes and fuel type.
- The use of existing pipe in a building may be permitted, but it may be necessary to perform pressurized leak checks with pressures that are higher than the normal service pressure.
- Fuel system must be designed to handle at least 1.5x the maximum operating pressure of the system. All piping and components must be rated higher than this pressure and the system should be pressure tested prior to microturbine commissioning. All piping systems should be protected from overpressure events.

- Fuel system must be designed to handle at least 1.5x the maximum load fuel flow, due to the fuel requirement for cold startups. This is an important consideration when selecting the diameter of system piping and components.
- Drip traps should be installed at any point in the line of pipe where condensation may occur. Drip traps must be easy to access and clean.
- Fuel lines should be sloped in such a manner as to direct any condensate into a separation vessel, drip leg, or serviceable area. If piping is installed underground, special consideration must be taken for collecting condensate and removing it. This may involve a sump tank and pump.
- Fuel lines should be painted in order to protect the pipe from corrosion and, as a safety feature, to discern fuel lines from other piping. Local code may determine, but a common fuel system color is yellow.

#### **6.5.8. Materials Selection**

In many cases coated carbon steel material can be used, but material selection will depend on the composition of the fuel being used. This applies to piping as well as other components such as regulators, compressors, valves, and vessels, as all these components are exposed to the fuel.

Sour gas containing H<sub>2</sub>S is corrosive, and liquid condensate may contain corrosive contaminants. Stainless steel, plastic, and aluminum are the preferred materials of construction for corrosive compounds. Brass and copper should not be used, and carbon steel will also eventually corrode; leaving byproducts that can clog and damage other equipment.

Plastic pipe is used in some locations but is not permitted in others. This type of pipe has the advantage of being corrosion-proof, but can be more-easily damaged by accident or by frozen water expansion during winter.

#### **6.5.9. Instrumentation and Controls**

Capstone recommends that temperature and pressure indicators be installed in order to better monitor and troubleshoot the system. Pressure and temperature transmitters, and other system controls can be added in order to add safety and response to the system. Some general controls examples are listed below, more detailed controls will be based on the specific components installed in the fuel system.

- High and low pressure alarms
- High and low temperature alarms
- Vapor-liquid separator and drip leg high level alarms
- Filter high pressure drop alarms
- Fuel tank level alarms.



### 6.5.10. Black Start/Dual Mode Considerations

There are unique concerns for fuel delivery when the microturbine is off grid, which occurs in standalone or dual mode applications. When not connected to a grid, the AC electrical bus will be “black” (zero voltage), and starting the microturbine in this state is known as a “black start.” Until the microturbine enters load state, auxiliary systems that rely on the AC bus for power will require an alternative power supply for this black start period. This means that an external gas compressor and other fuel system auxiliaries, such as dryers, automatic valves, and condensate equipment, will need an external power source during a black start.

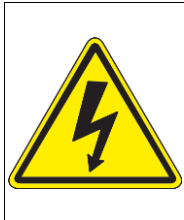

Two common black start power supplies include a small piston generator or a UPS system. The black start power supply should be rated for the voltage, power, and time requirements of the black start period. The transition from black start power supply to microturbine power supply is a critical period, since the microturbine needs to remain operational through this transition. Controllers generally include dedicated UPS systems that can ride through short outages, but these will not generally help for the larger compressor and auxiliary power supply requirement.

## 6.6. Liquid Fuel

Liquid fuels and liquid fuel delivery systems vary greatly from gaseous fuels. Liquid fuels are commercially available in a variety of different forms, such as gasoline, diesel fuel, biodiesel, and jet fuel. Certain oil and gas installations will also have access to fuels such as raw gasoline and diesel, liquid hexanes, kerosene and heavy gas oils. Due to the continuous combustion process of a microturbine and Capstone’s experience using some of these fuels, not all of these liquid fuels are acceptable for use in a microturbine.

Liquid fuels are not similar to gaseous fuels, and therefore special consideration must be taken with every component in the liquid fuel system. If installing a liquid fuel system, refer to the Liquid Fuel Application Guide (Table 1) and C1000 Liquid Fuel Pretreatment P&ID (Table 1) for information on allowable fuels, properties, requirements, and delivery.

## 7. Electrical Installation

	<p style="text-align: center;"> <b>ELECTRICAL WARNING</b></p> <p>Consult all applicable codes and industry standards before connecting the interface wiring for the microturbine. A qualified electrician may be required to perform this work. Failure to observe this warning can result in personal injury or equipment damage.</p>
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### 7.1. General Requirements


It is the responsibility of the installer to supply all ancillary electrical equipment such as electrical cable, switchgear, transformers, and disconnects through which the microturbine delivers its output power. The equipment must be capable of safely handling the maximum potential loads, and must meet all applicable local and national regulations. This section outlines general requirements for all Capstone products.

#### 7.1.1. Electrical Connections Considerations


The information here is intended to help avoid common mistakes and highlight possible permitting issues.

- Electrical service to the microturbine location may come underground, above ground, supported from ceiling, or attached to wall per local codes, but note the following:
  - The depth that conduits must be buried changes based on whether the conduit is under a building, parking lot, or concrete of different thicknesses.
  - Above-equipment conduit runs may be subject to height and support requirements per applicable mechanical and electrical codes.
- Grounding must be made in a manner that is consistent with local codes. Sheet metal screws are generally not permitted to attach ground leads or lugs to equipment. Refer to Section 7.2 for more details on microturbine grounding.
- Follow the typical rates for circuit breaker and wire sizing in accordance with applicable electrical and safety codes. Refer to Section 7.3 for more information on overcurrent protection.
- It is recommended that a lockable disconnect be installed within viewing distance of the microturbine, and is used to isolate the microturbine for service or repair.
- Conductor size and insulation type must be determined based on total maximum nameplate rating of the microturbine units.
- Always perform a load analysis to determine a customer's electrical demand and power quality requirements (harmonics). These requirements should drive the final design for the project.

	<b>NOTE</b>
<p>3-wire delta utility service connections require a grounding transformer, as phase-to-ground voltages float and, over time, become unbalanced with respect to ground which causes microturbine hardware damage and nuisance trips. In addition, the phase-to-ground voltages reach levels that can break the insulation in the IGBTs-to-ground and cause equipment failure. Capstone Applications approval is required for grounding transformer applications.</p>	

	<b>NOTE</b>
<p>High power and communication wiring must be run in separate metal grounded conduits or trays to reduce noise issues.</p>	

### 7.1.2. Phase Sequence


	<b>CAUTION</b>
<p>For Stand Alone or Dual Mode installations, improper phase connections can damage the connected loads or cause microturbine trips. Capstone cannot be held responsible for equipment damage caused by improper connections. It is the installer's responsibility to verify the proper phase connections between the microturbine and the load(s). The output phase sequence of the microturbine is L1 to L2 to L3 (A to B to C).</p>	

## 7.2. Grounding Requirements




### 7.2.1. Protective Earth (PE) / Chassis Ground

All Capstone microturbines must have protective earth (PE) grounding for the chassis. A separate ground bar is included in the power connection bay for this purpose. PE grounding is commonly provided via ground rod installation. The PE for the chassis ground and the ground for the neutral should be at equivalent potentials, with respect to earth. Use of a single PE connection for multiple microturbine chassis grounds is acceptable.

PE/chassis grounding can either be a ground rod at each unit, a common ground rod for all units, or a single, common ground rod at the utility transformer or main distribution panel.

	<b>NOTE</b>
<p>All illustrations in this document indicate the protective earth (PE)/ chassis ground by "PE/G".</p>	

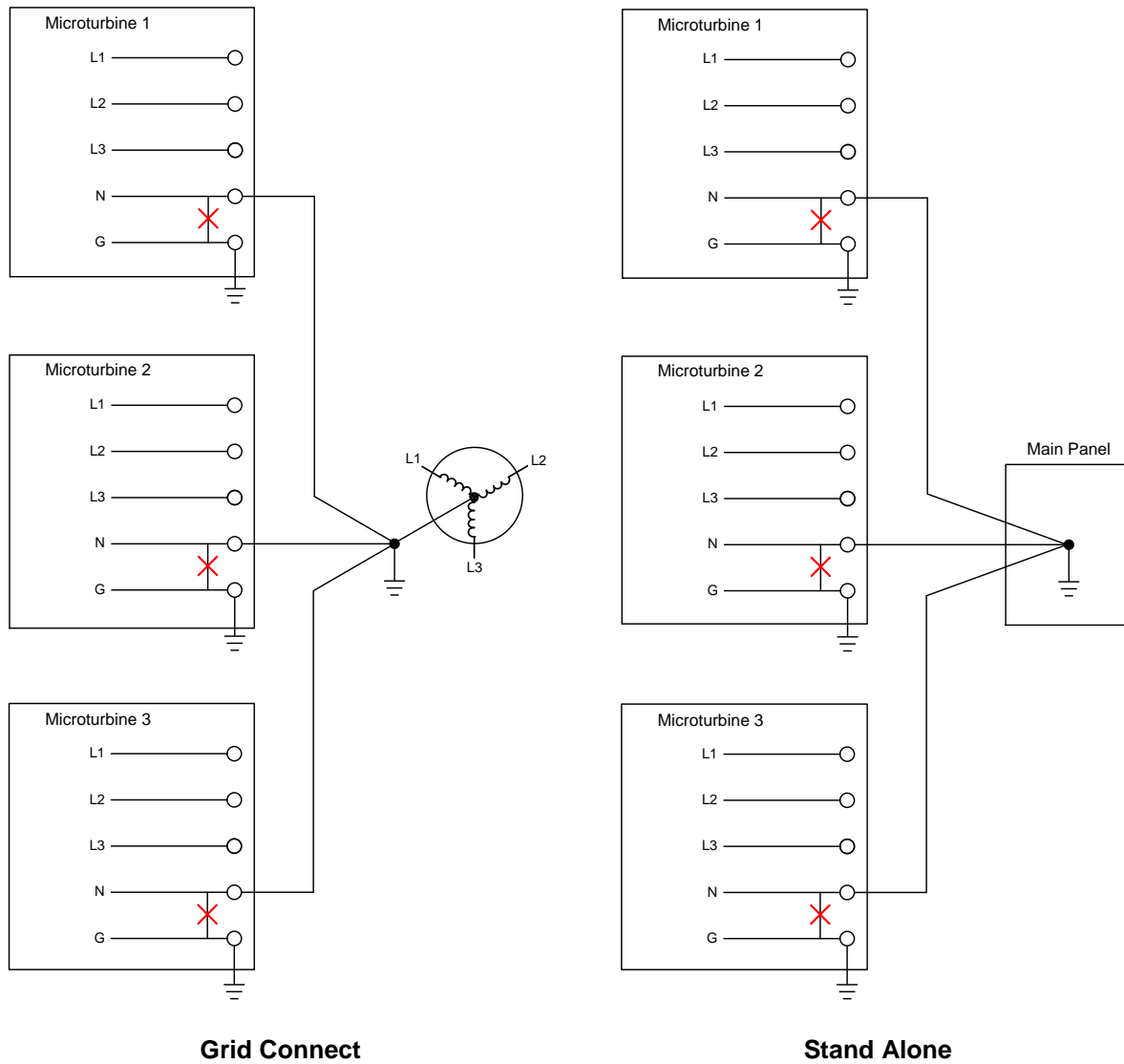
### 7.2.2. Grounding the Microturbine Neutral

	<p style="text-align: center;"><b>CAUTION</b></p> <p>GROUNDING REQUIREMENT. A solid earth ground — 5 <math>\Omega</math> or less — of the microturbine neutral is MANDATORY for successful operation. Any high-impedance grounding scheme MUST BE APPROVED BY CAPSTONE PRIOR TO COMMISSIONING. Failure to observe this caution may result in equipment damage.</p>
	<p style="text-align: center;"><b>CAUTION</b></p> <p>All microturbine installations must have the neutral wire correctly grounded for proper operation. Failure to correctly ground the neutral — i.e. no neutral-to-ground connection or more than one neutral-to-ground connection — can damage the system.</p>
	<p style="text-align: center;"><b>NOTE</b></p> <p>A high impedance or resistive ground is not necessary due to the very low fault current contribution of the microturbine — approximately 2x nominal current — and should be avoided when possible. If a high impedance ground is required, a modification to the microturbine and additional external surge protection equipment must be approved by Capstone Applications Engineering and will be supplied by the installer.</p>

It is recommended that neutral wire(s) only ground in a single location, unless local code requires more than one connection. For example, it is sometimes required by local code to ground the neutral before the conductor leaves one building and travels into another, in case the neutral is broken during earthmoving activities. In the case of multiple grounding points, these grounding points should be at equivalent potentials; otherwise circulating currents can occur and provide a poor reference for operation. See Figure 26 for proper neutral-to-ground connection.

For Grid Connect installations, the required location of the neutral-to-ground connection is at the utility service panel or the utility service transformer. A neutral-to-ground connection is often already present at the Wye utility service transformer.


For Stand Alone and Dual Mode installations, the recommended location of the neutral-to-ground connection is at the microturbine service panel. Use of four-pole breakers may necessitate multiple neutral-to-ground connections, and more information is provided on this subject in Section 7.7.



**Figure 26. Microturbine Neutral-to-Ground Connection**

There are several reasons for this requirement:

- In Grid Connect operation, the microturbine voltage reference is taken from each phase to neutral. If the microturbine's phase-to-neutral voltage does not match the transformer's phase-to-neutral voltage, the generated power may not match the actual power into the grid. This could generate excessive or deficient levels of current out of the microturbine, and cause nuisance under-voltage or over-voltage trips.
- For Stand Alone operation, all neutrals must be tied at the same point, even if there are no single-phase loads. Even when there are no single-phase loads, there will be current flowing through the transformer, due to the harmonics generated by the inverters. Therefore, this requirement is completely independent of the existence of single-phase loads. Do not undersize neutral conductors. Inverter switching frequency can increase the cable impedance between neutral and ground connections from each microturbine, which in turn will yield a higher voltage differential between neutral and ground.
- Individual neutrals from each microturbine grounded at the same point ensures all microturbines are reading the same voltage reference.

	<div data-bbox="829 787 971 835" data-label="Section-Header"><h2>NOTE</h2></div> <p data-bbox="386 871 1421 940">If multiple neutral-to-ground connections are required, please contact your local Capstone Turbine authorized distributor for approval.</p>
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### 7.3. Overcurrent Protection and Disconnecting Devices

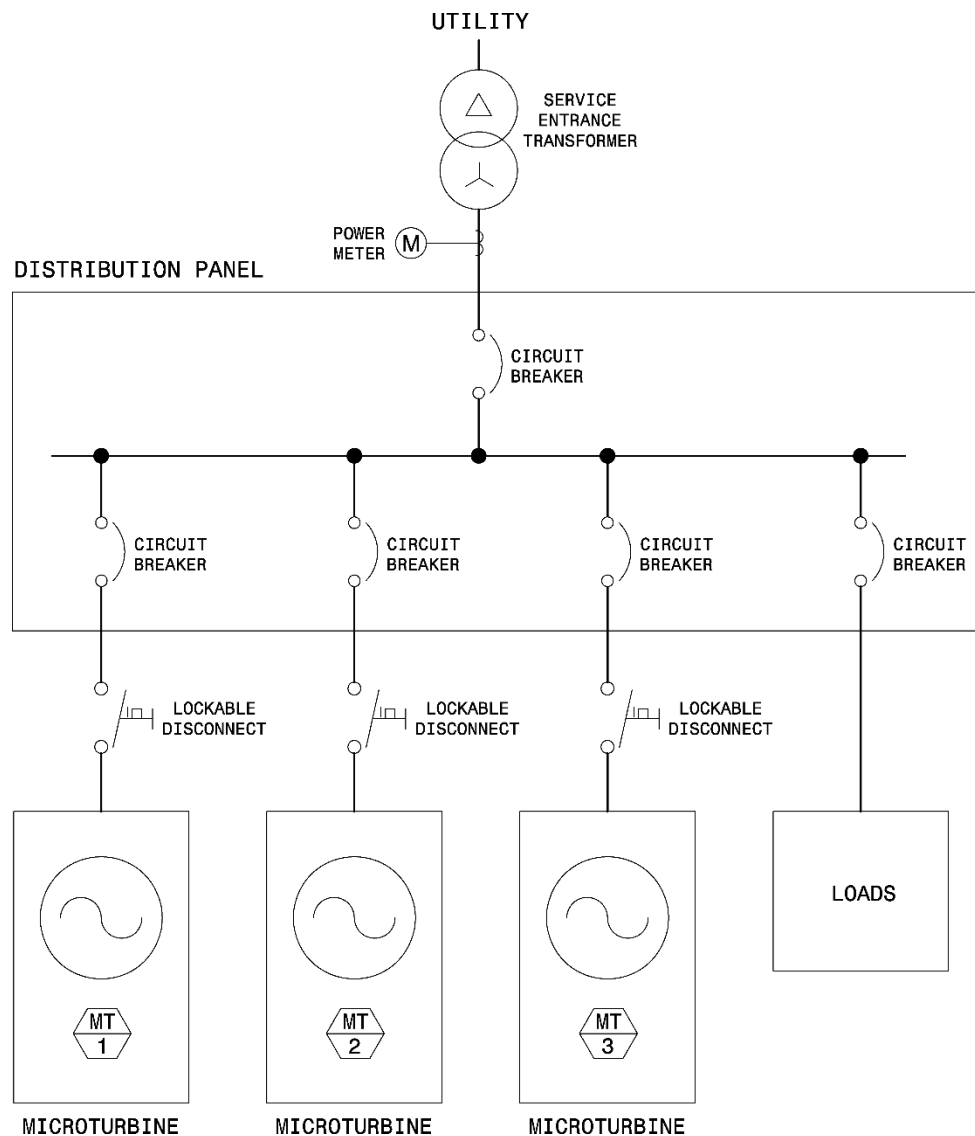
Overcurrent protection is required for each microturbine, usually by circuit breaker or fused disconnect. This overcurrent protection device must be installed between the microturbine and the electrical bus connection. The type and fault-current ratings of the device must meet the nameplate ratings for each microturbine model as well as meet all local codes and specifications. Table 12 gives recommended sizing for overcurrent protection devices.

**Table 12. Overcurrent Protection Sizing**

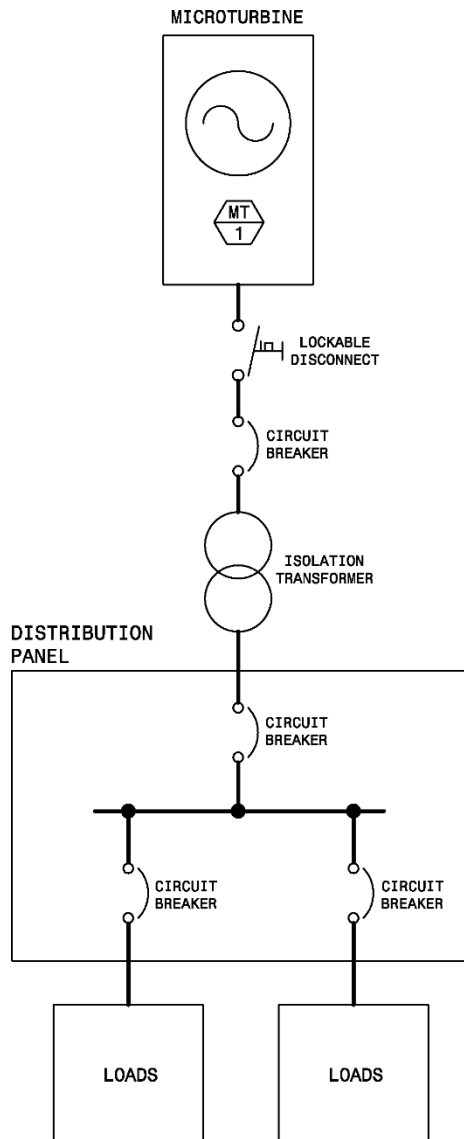
Microturbine Model	Recommended Trip Setting
C600	1200 AT
C800	1600 AT
C1000	2000 AT

If future capacity upgrades are planned for a C600 or C800 to a C1000, the larger frame size can be used and the trip setting adjusted accordingly. If a fused disconnect switch is used instead of circuit breaker, then fast-acting, current-limiting fuses — installed on the microturbine side of the switch — are recommended.

Any disconnect device should have lockout provisions to facilitate safe maintenance operations. In the event that the service panel and microturbine are very near, it may be acceptable to use the overcurrent protection device as this lockable disconnect. Depending on local codes, a lockable disconnect may not be required, but a means of isolating the microturbine for service and maintenance is required. Please note that most circuit breakers will require additional hardware to become “lockable”. In the event of a long distance between the microturbine and the service panel, this should be a separate lockable switch. Figure 27 shows the recommended configuration for multiple microturbines connected to a grid. Figure 28 shows the recommended configuration for a microturbine as Stand Alone power source.



**Figure 27. Recommended Device Layout – Grid Connect**



**Figure 28. Recommended Device Layout – Stand Alone**

### 7.3.1. CE Disconnect Requirements

For CE installations, the disconnect device must be one of the following types:

- Switched disconnect device per IEC 60947-3, utilization category AC-23B or DC-23B.
- Disconnect device per IEC 60947-3 with an auxiliary contact that in all cases causes switching devices to break the load circuit before the opening of the main contacts of the disconnect device
- A circuit breaker suitable for isolation in accordance with IEC 60947-2

The operating means of the disconnect device must be easily accessible and located between 0.6 and 1.9 m (2.0 and 6.2 feet) above the servicing level. An upper limit of 1.7m (5.6 ft) is recommended.



## 7.4. Transformer Requirements


### 7.4.1. Transformer Applications

A voltage transformer for the microturbine is required if the circuit voltage is outside the 400 to 480 V<sub>AC</sub> range.

All Grid Connect mode installations with transformers between the microturbine and the grid — point in the distribution grid where the voltage is 6 kV or higher — must consider maximum grid impedance. Proper sizing of transformers in the installation is required to limit the impedance seen by the microturbine. Refer to the input impedance calculation in paragraph 7.4.3.

### 7.4.2. Transformer Sizing

The sizing recommendations in Table 13 are provided for any installation requiring a transformer.

	<b>NOTE</b>
	For Stand Alone or Dual Mode installations with multiple microturbines, it is required to parallel all microturbines on the 400/480 V side. If transformers are required, then these should be tied at the 400/480 V at different points so that the current capacity of the 400/480 bus bar is not exceeded by any segment.

**Table 13. Recommended Transformer Sizes (Per System)**


Model <sup>(1)</sup>	Voltage	Fuel	Microturbine kVA Rating	Transformer Size <sup>(2)</sup>	
				Low Harmonics (<5% THD) <sup>(3)</sup>	High Harmonics (>5% THD) <sup>(4)</sup>
C1000S (GC)	400 V	All HP Gaseous LPNG	1040 kVA	1.3 MVA	1.5 MVA
	480 V	All HP Gaseous LPNG	1040 kVA 1110 kVA 1055 kVA		
C1000S (SA)	400 V	All HP Gaseous LPNG	1040 kVA	1.3 MVA	1.5 MVA
	480 V		1250 kVA	1.5 MVA	1.7 MVA
C800S (GC)	400 V	All HP Gaseous LPNG	832 kVA	1.0 MVA	1.2 MVA
	480 V	All HP Gaseous LPNG	832 kVA 888 kVA 844 kVA	1.2 MVA 1.1 MVA	1.3 MVA
C800S (SA)	400 V	All HP Gaseous LPNG	832 kVA	1.0 MVA	1.2 MVA
	480 V		1000 kVA	1.2 MVA	1.4 MVA
C600S (GC)	400 V	All HP Gaseous LPNG	624 kVA	900 kVA	1 MVA
	480 V	All HP Gaseous LPNG	624 kVA 666 kVA 633 kVA		
C600S (SA)	400 V	All HP Gaseous LPNG	624 kVA	800 kVA	900 Kva
	480 V		750 kVA	900 kVA	1 MVA

**Table 13 Notes:**

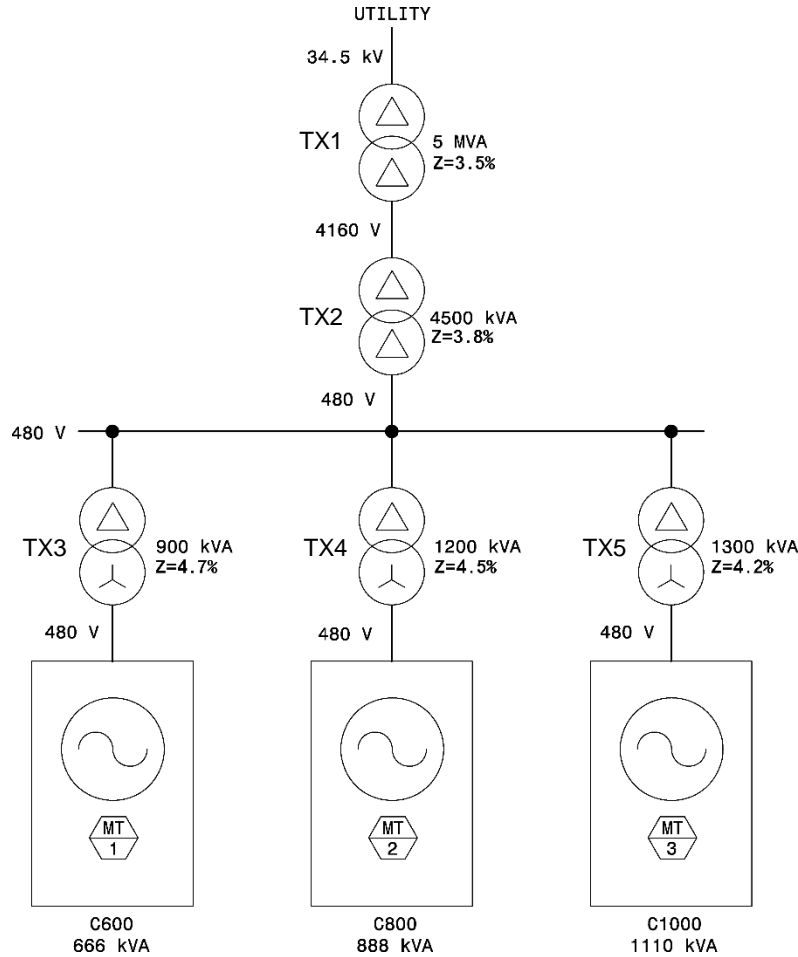
- (1) For Dual Mode configuration, equipment should be sized per Stand Alone (SA) ratings.
- (2) If not in specification, refer to Section 7.8 for harmonics requirements.
- (3) 20 to 25% of microturbine kVA rating.
- (4) 40% microturbine kVA rating.

### 7.4.3. Grid Connect Input Impedance Calculation

The following examples provide an input impedance calculation per microturbine based on a typical transformer installation, as shown in Figure 29 and Figure 30. The calculations below are checking inductive impedance only, as this is generally the limiting factor, not the resistive impedance.

	<div data-bbox="836 604 971 653"><b>NOTE</b></div> <p data-bbox="391 701 1240 737">Input impedance calculations are for Grid Connect operation only.</p>
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#### 7.4.3.1. Example 1 – 480V Operation



**Figure 29. Typical Transformer Installation with Impedance Percentages – 480 V**

##### Microturbine #1 (C600S with 666 kVA):

$$Z = 4.7\% \left( \frac{666 \text{ kVA}}{900 \text{ kVA}} \right) + 3.8\% \left( \frac{666 \text{ kVA} + 888 \text{ kVA} + 1110 \text{ kVA}}{4500 \text{ kVA}} \right) + 3.5\% \left( \frac{666 \text{ kVA} + 888 \text{ kVA} + 1110 \text{ kVA}}{5000 \text{ kVA}} \right) + 0.5\%$$

$$Z = 8.09\%$$

##### Microturbine #2 (C800S with 888 kVA):

$$Z = 4.5\% \left( \frac{888 \text{ kVA}}{1200 \text{ kVA}} \right) + 3.8\% \left( \frac{666 \text{ kVA} + 888 \text{ kVA} + 1110 \text{ kVA}}{4500 \text{ kVA}} \right) + 3.5\% \left( \frac{666 \text{ kVA} + 888 \text{ kVA} + 1110 \text{ kVA}}{5000 \text{ kVA}} \right) + 0.5\%$$

$$Z = 7.94\%$$

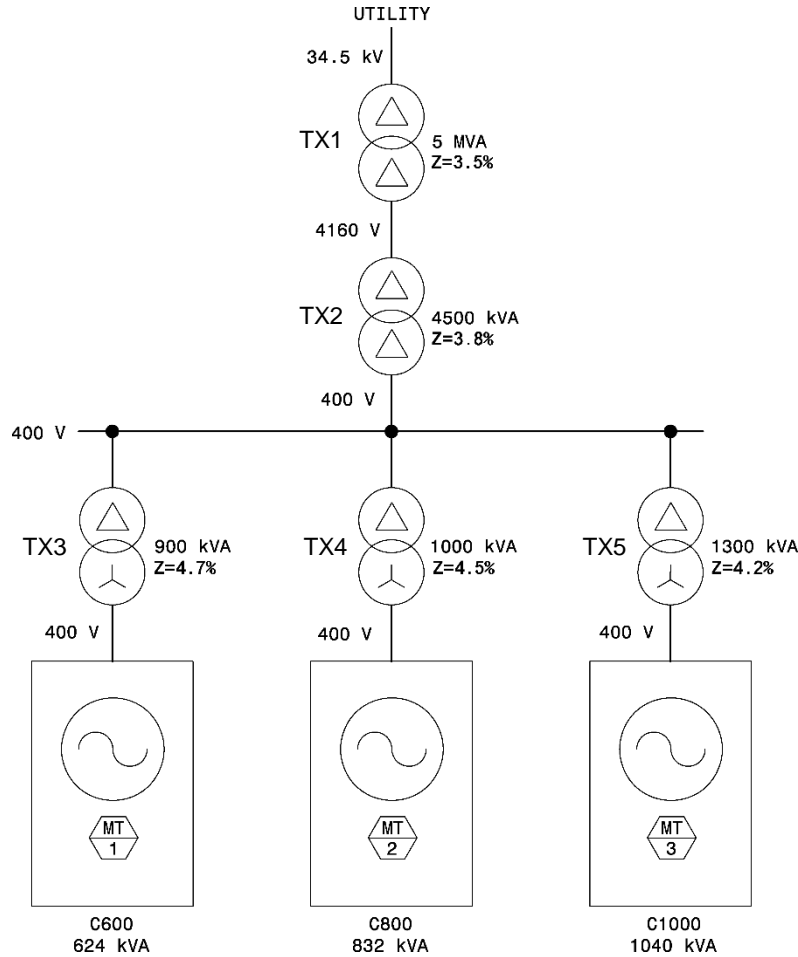
##### Microturbine #3 (C1000S with 1110 kVA):

$$Z = 4.2\% \left( \frac{1110 \text{ kVA}}{1300 \text{ kVA}} \right) + 3.8\% \left( \frac{666 \text{ kVA} + 888 \text{ kVA} + 1110 \text{ kVA}}{4500 \text{ kVA}} \right) + 3.5\% \left( \frac{666 \text{ kVA} + 888 \text{ kVA} + 1110 \text{ kVA}}{5000 \text{ kVA}} \right) + 0.5\%$$

$$Z = 8.20\%$$

Since the calculated inductive impedances are less than the 10% maximum listed in the C1000S/C800S/C600S Technical Reference (Table 1), the system design is acceptable.

#### 7.4.3.2. Example 2 – 400V Operation



**Figure 30. Typical Transformer Installation with Impedance Percentages – 400 V**

##### Microturbine #1 (C600S with 624 kVA):

$$Z = 4.7\% \left( \frac{624 \text{ kVA}}{900 \text{ kVA}} \right) + 3.8\% \left( \frac{624 \text{ kVA} + 832 \text{ kVA} + 1040 \text{ kVA}}{4500 \text{ kVA}} \right) + 3.5\% \left( \frac{624 \text{ kVA} + 832 \text{ kVA} + 1040 \text{ kVA}}{5000 \text{ kVA}} \right) + 0.5\%$$

$$Z = 7.61\%$$

##### Microturbine #2 (C800S with 843 kVA):

$$Z = 4.5\% \left( \frac{843 \text{ kVA}}{1000 \text{ kVA}} \right) + 3.8\% \left( \frac{624 \text{ kVA} + 832 \text{ kVA} + 1040 \text{ kVA}}{4500 \text{ kVA}} \right) + 3.5\% \left( \frac{624 \text{ kVA} + 832 \text{ kVA} + 1040 \text{ kVA}}{5000 \text{ kVA}} \right) + 0.5\%$$

$$Z = 8.11\%$$

##### Microturbine #3 (C1000S with 1040 kVA):

$$Z = 4.2\% \left( \frac{1040 \text{ kVA}}{1300 \text{ kVA}} \right) + 3.8\% \left( \frac{624 \text{ kVA} + 832 \text{ kVA} + 1040 \text{ kVA}}{4500 \text{ kVA}} \right) + 3.5\% \left( \frac{624 \text{ kVA} + 832 \text{ kVA} + 1040 \text{ kVA}}{5000 \text{ kVA}} \right) + 0.5\%$$

$$Z = 7.04\%$$

Since the calculated inductive impedances are less than the 10% maximum listed in the C1000S/C800S/C600S Technical Reference (Table 1), the system design is acceptable.



## NOTE

As seen from the examples above, the total impedance will increase with the number of transformers in series. The recommended practice is to install the least amount of transformers between the MTs and the highest voltage connection point. In the examples above, it would be recommended to remove TX2 and change TX1 voltage ratio to 34.5 kV/480 V in example 1. In example 2, TX1 would have a ratio of 34.5 kV/400 V.

### 7.4.4. Transformer Benefits for 480/400 V Operation in Grid Connect

For 400 V applications, using an operating voltage of 480 V on the microturbine side of the transformer allows for full power output without de-rate at a power factor of +/- 0.9. This is due to the current limit of each 200 kW module being limited to 300 A.

### 7.4.5. Transformers for Stand Alone

For any Stand Alone installation with highly non-linear loads, an isolation transformer is required. In addition to reducing harmonics, there are two major benefits that are worth consideration. First, the energy storage in the transformer windings reduces voltage drop during motor direct on-line (DOL) starts. Second, for 400 V applications, using an operating voltage of 480 V on the microturbine side of the transformer provides up to 20% higher kVA margin for starting large electric loads.

For sites requiring an isolation transformer, the recommended configuration is as follows:


- Delta connection on microturbine side.
- Wye connection is recommended on load side. However, delta connection on load side is also acceptable if required by installation.
- 480 V output setting on microturbine side. This may not be commercially available in all countries.
- Impedance between 4-8%. Lower impedance provides better overall voltage regulation, but may require configuration of a soft start ramp on the microturbines for installations with three or more microturbines, due to the larger inrush current to energize the transformer. The voltage ramp and frequency ramp start features are discussed in the CRMS Maintenance TR 410014.



## NOTE

Autotransformers are not allowed as an alternative to the required isolation transformer, since they do not provide the galvanic isolation and delta winding which minimize the transmission of harmonics.

## 7.5. Grid Connect Mode

	NOTE
	<p>Not all of the allowable utility service connections for the various microturbine operating modes are presented in this document. Consult your local Capstone Turbine authorized distributor if your utility service connections do not agree with those presented in this document.</p>

Grid Connect mode provides alternating current (AC) electrical power in parallel with a utility grid or with another generation source. Grid Connect mode includes built-in utility-synchronization capability and protective relay functions. In this mode the microturbine acts as a current source, controlling its current output to meet the commanded power output at the rated voltage.

In grid-parallel applications with variable electric loads, economics or utility restrictions may require that no power, or limited power, be exported to the utility. This requirement can be met using an external power meter. Using power meter signals, a turbine can dynamically adjust its output power level to ensure that limited or zero power flows back to the utility. This application is called Load Following.

### 7.5.1. Grid Connections

#### 7.5.1.1. Grid Connect Allowable Configurations

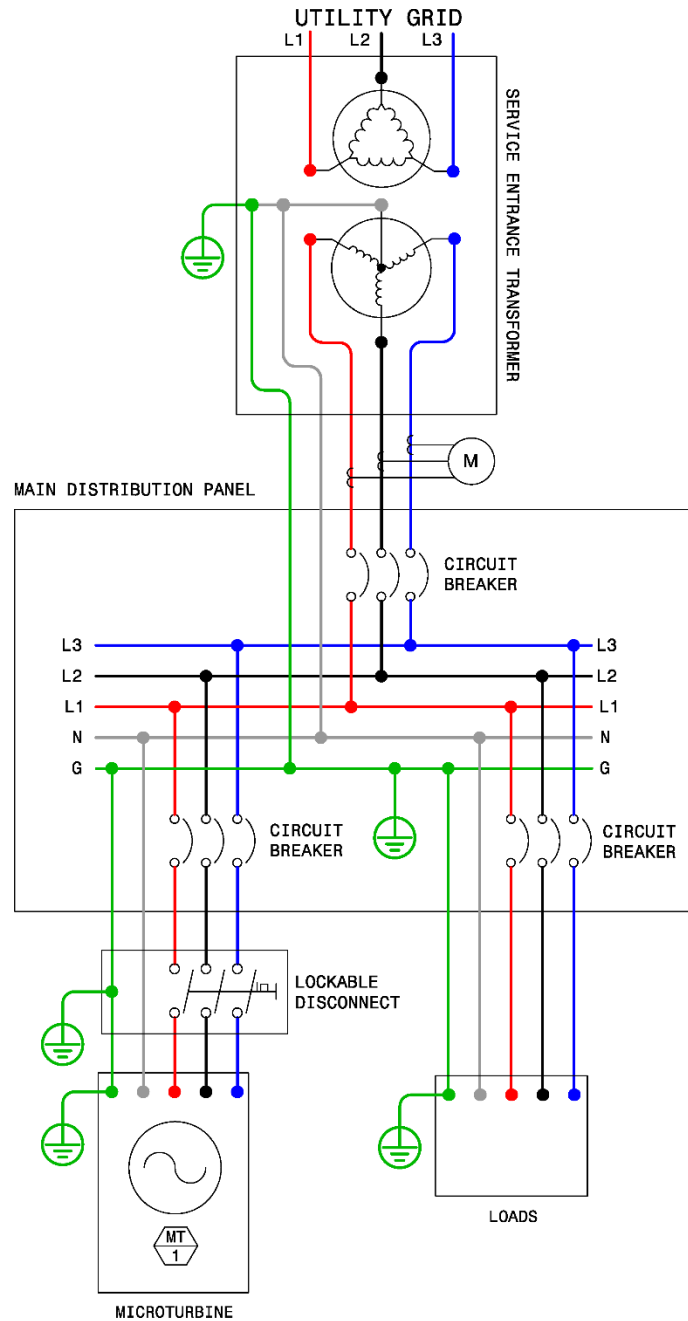
See Figure 31 through Figure 38 for examples of allowable microturbine grid connections. Examples of CE and UL systems are shown for each type of grid connection. Table 14 provides a list of allowable configurations.

**Table 14. Grid Connect Allowable Configurations Matrix**

Figure No.	Standards Compliance		Service Entrance Transformer		Microturbine Transformer Type	Comments
	UL1741	CE	Wye	Delta		
1	X		X		N/A	
2		X	X		N/A	
3	X		X		Wye/Wye Isolation	Isolation transformer can be used as step-up/step-down to meet voltage requirements
4		X	X		Wye/Wye Isolation	Isolation transformer can be used as step-up/step-down to meet voltage requirements
5	X			X	Delta/Wye Isolation	Service entrance transformer (delta) can be ungrounded with ground fault protection, corner grounded, or center tapped grounded

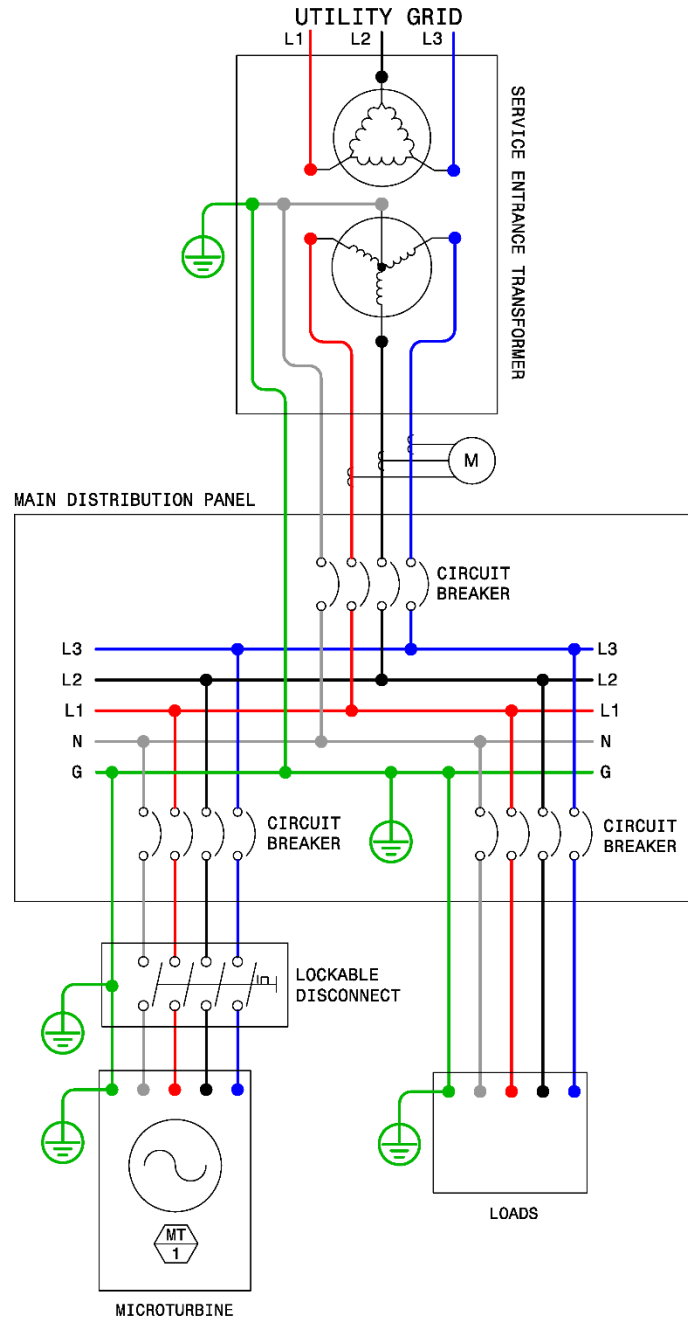
**Table 14. Grid Connect Allowable Configurations Matrix (Continued)**

Figure No.	Standards Compliance		Service Entrance Transformer		Microturbine Transformer Type	Comments
	UL1741	CE	Wye	Delta		
6		X		X	Delta/Wye Isolation	Service entrance transformer (delta) can be ungrounded with ground fault protection, corner grounded, or center tapped grounded
7				X	Zig Zag (Grounding)	Zig Zag transformer ensures delta service voltages are not able to float with respect to ground. Configuration requires Capstone Application approval.
8		X		X	Zig Zag (Grounding)	Zig Zag transformer ensures delta service voltages are not able to float with respect to ground. Configuration requires Capstone Application approval.

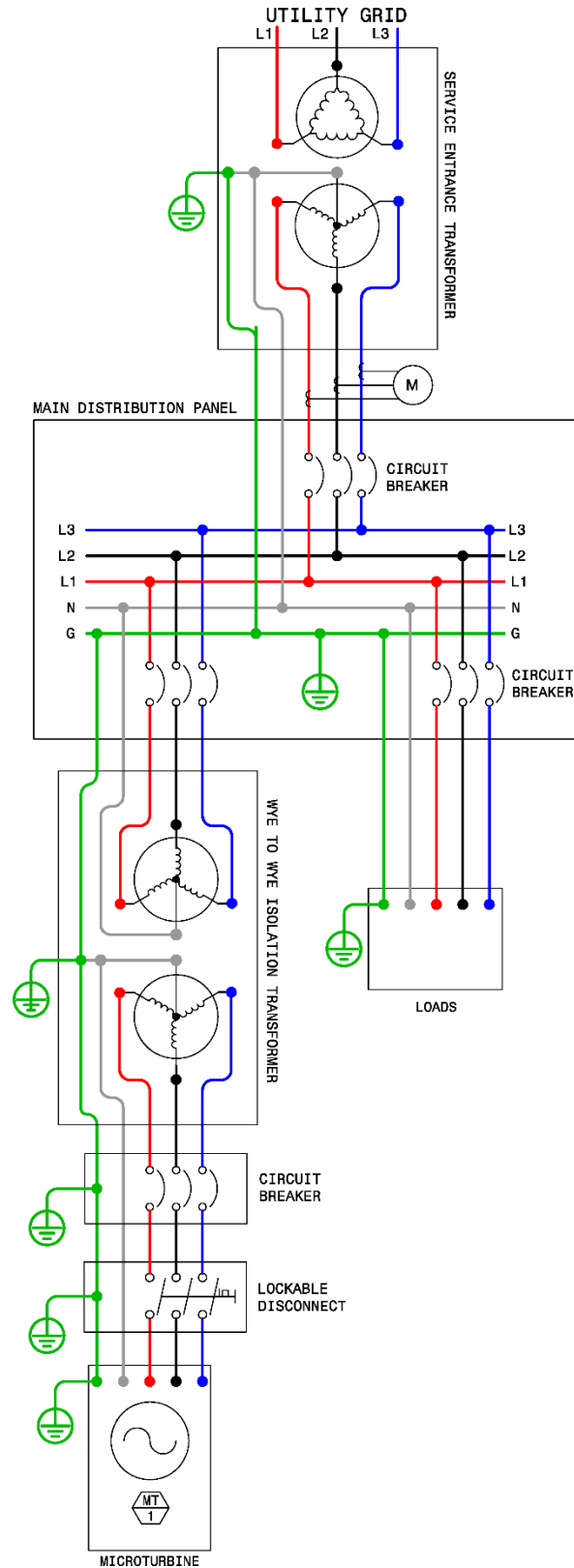


**Figure 31. Wye Service with 3-Pole Breaker**

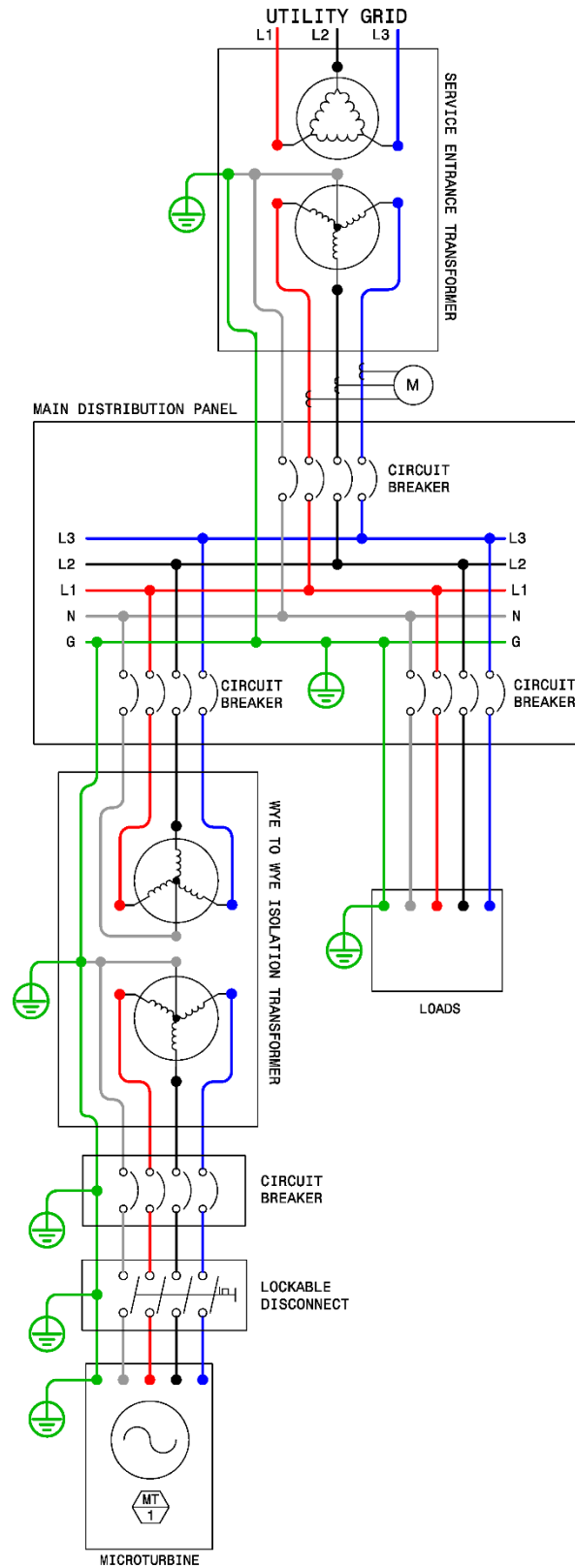




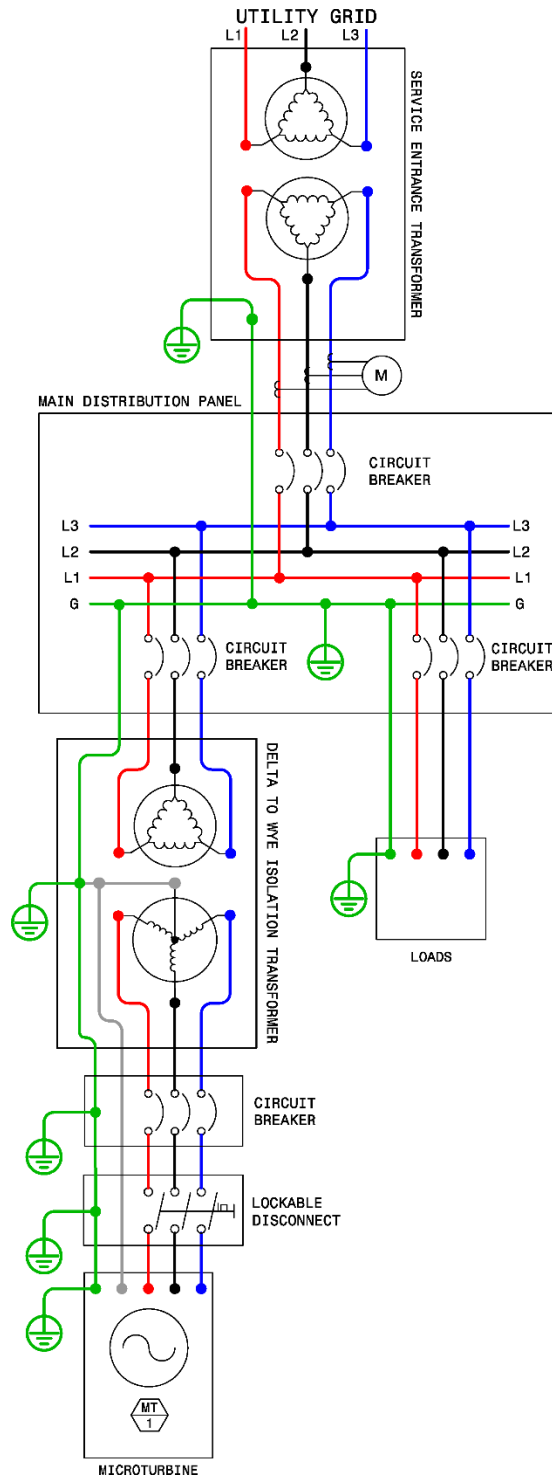
**Figure 32. Wye Service with 4-Pole Breaker**



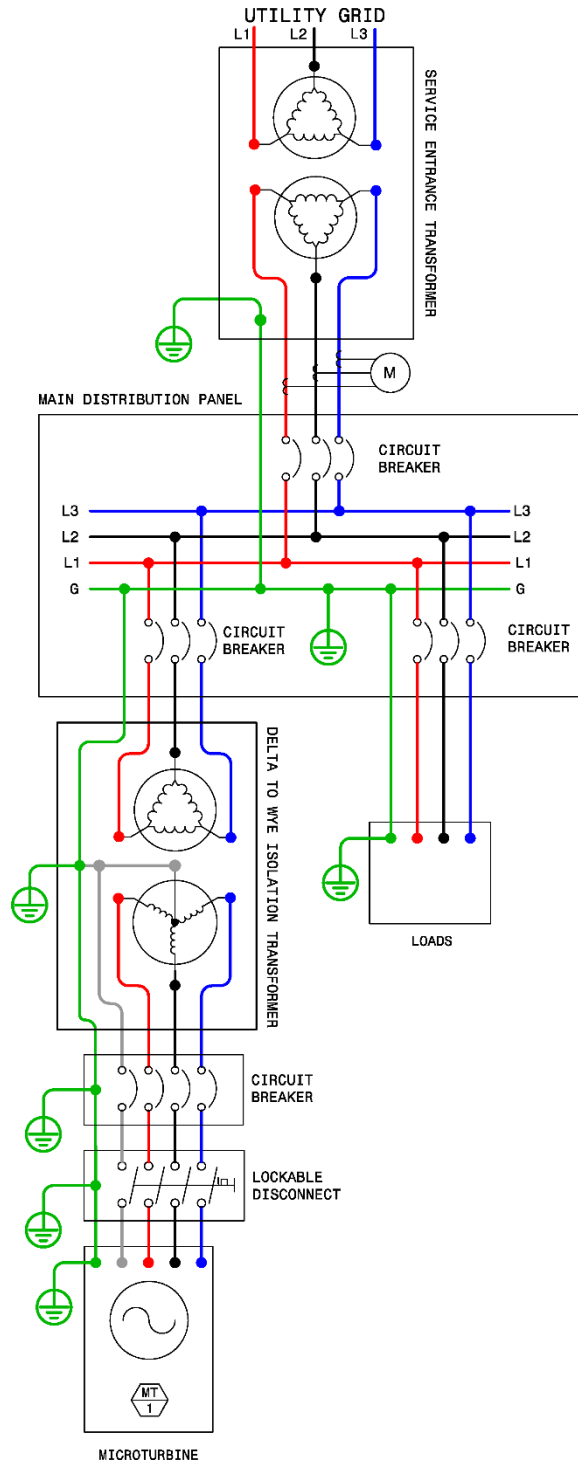
**Figure 33. Wye Service with Wye/Wye Isolation Transformer and 3-Pole Breaker**



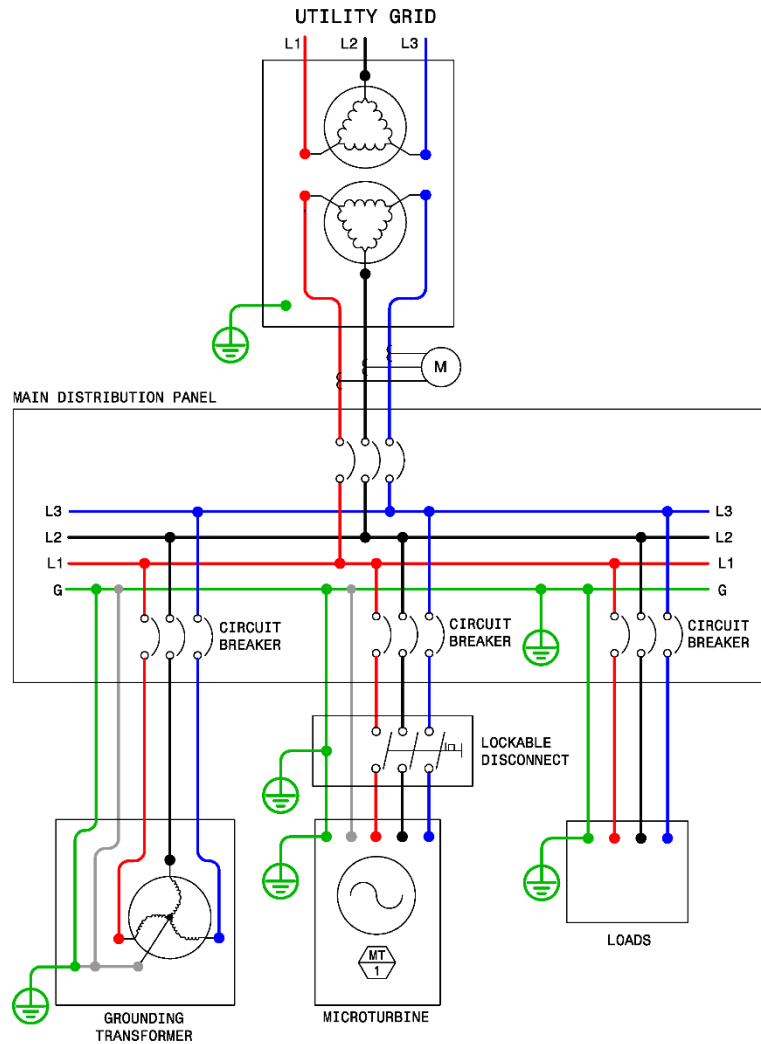
**Figure 34. Wye Service with Wye/Wye Isolation Transformer and 4-Pole Breaker**



**Figure 35. Delta Service with Delta/Wye Isolation Transformer and 3-Pole Breaker**



**Figure 36. Delta Service with Delta/Wye Isolation Transformer and 4-Pole Disconnect**

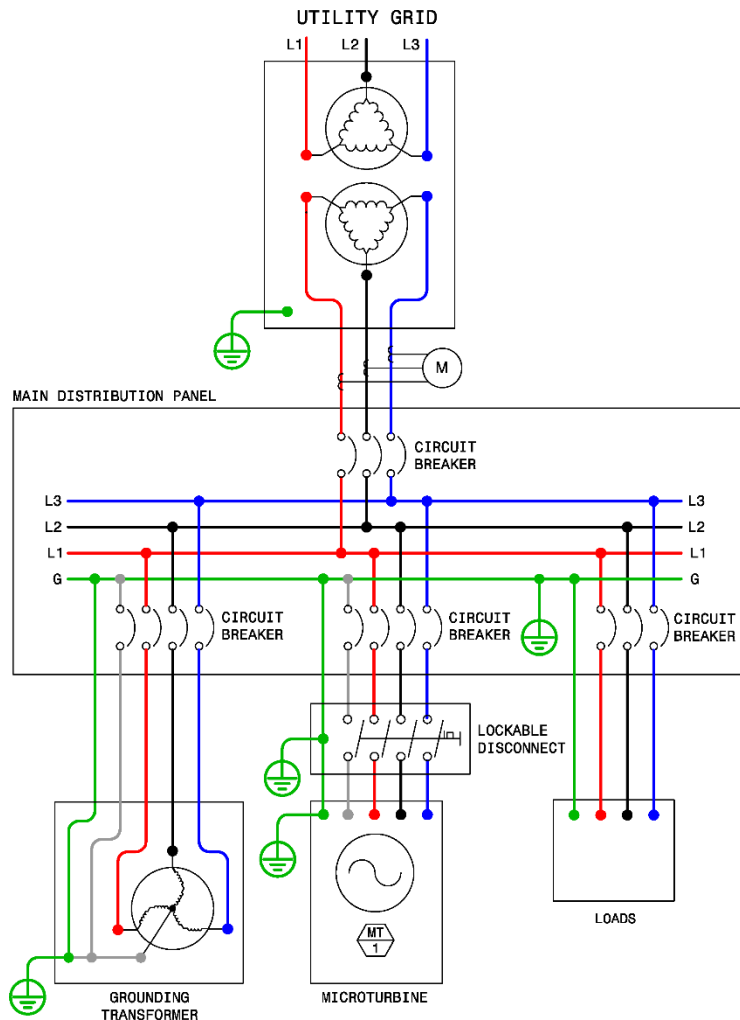


**Figure 37. Delta Service with Grounding Transformer and 3-Pole Breaker**



## NOTE

3-wire delta utility service connections require a grounding (zig zag) transformer, as phase-to-ground voltages float and, over time, become unbalanced with respect to ground which causes microturbine nuisance trips. In addition, the phase-to-ground voltages reach levels that can break the insulation in the IGBTs-to-ground and cause equipment failure. Capstone Applications approval is required for grounding transformer applications.



**Figure 38. Delta Service with Grounding Transformer and 4-Pole Breaker**

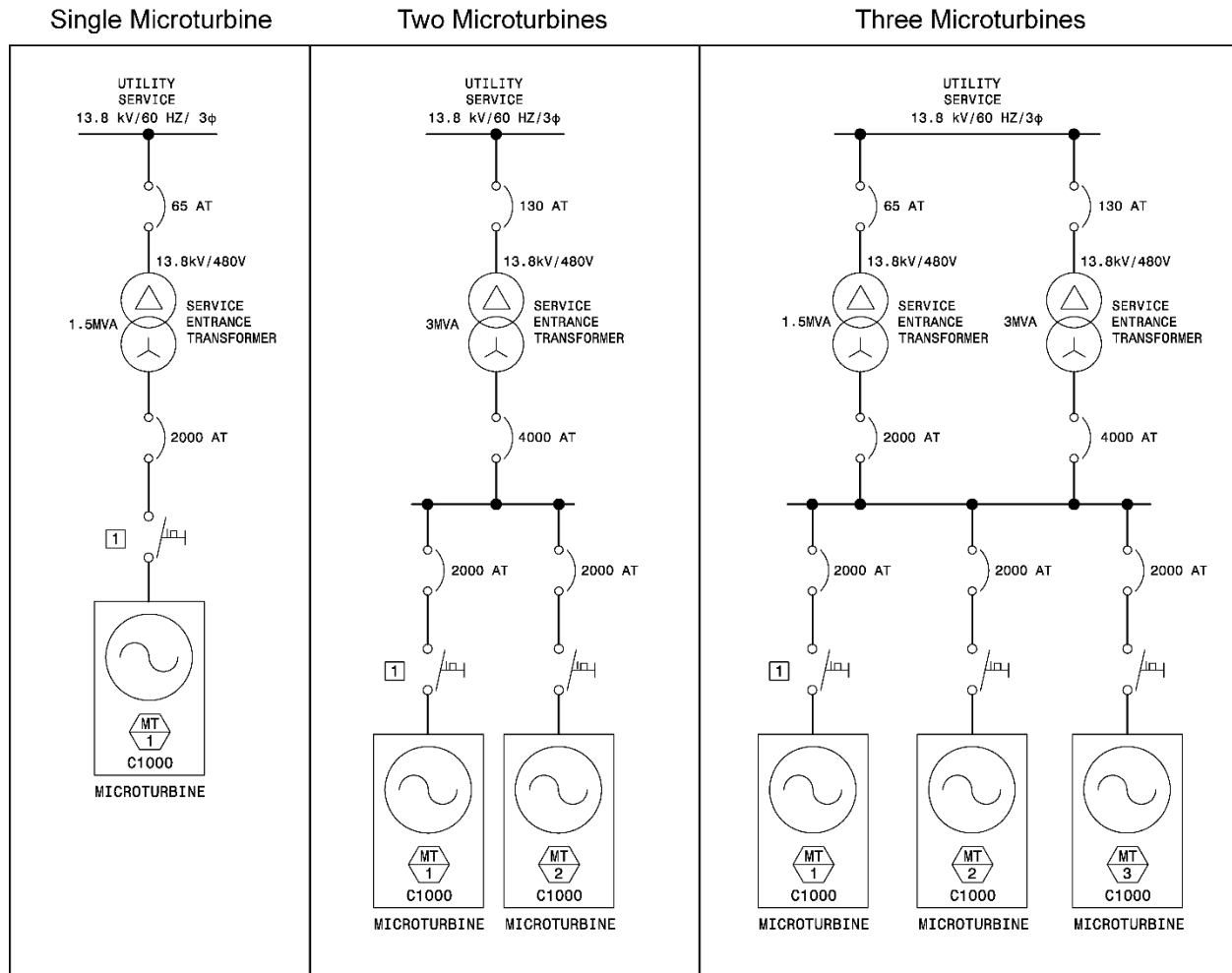


## NOTE

3-wire delta utility service connections require a grounding (zig zag) transformer, as phase-to-ground voltages float and, over time, become unbalanced with respect to ground which causes microturbine nuisance trips. In addition, the phase-to-ground voltages reach levels that can break the insulation in the IGBTs-to-ground and cause equipment failure. Capstone Applications approval is required for grounding transformer applications.

### 7.5.1.2. Examples of Single Line Diagrams

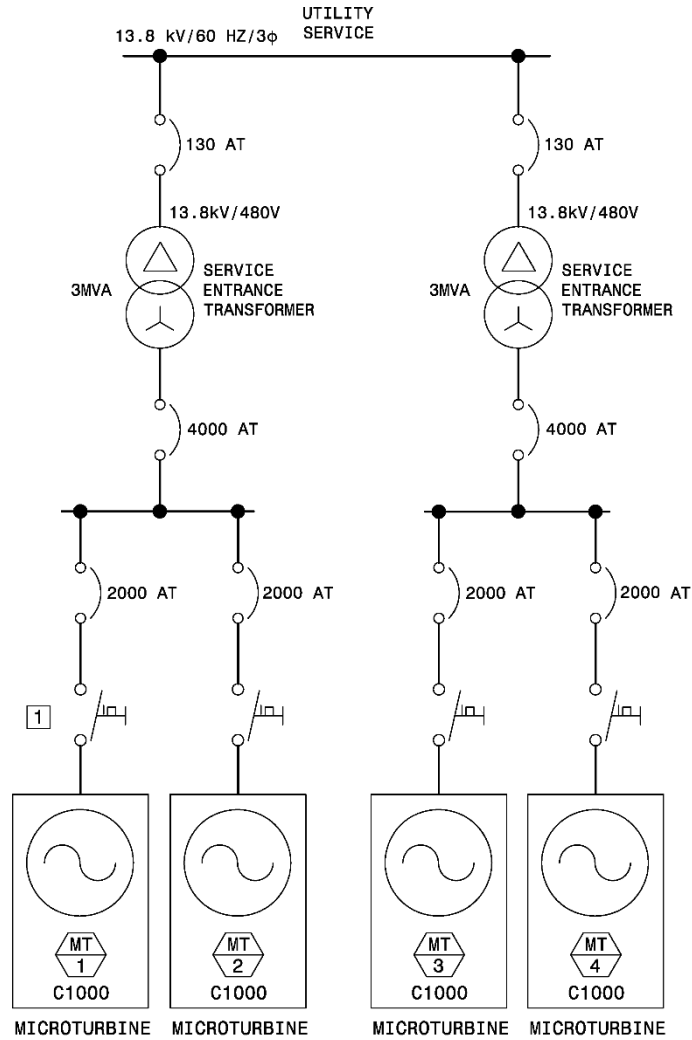
See Figure 39 through Figure 41 for Grid Connect installation single line diagrams for multiple microturbines.



1 LOCKABLE DISCONNECT VISIBLE FROM EACH MT MAY BE REQUIRED BY LOCAL CODE

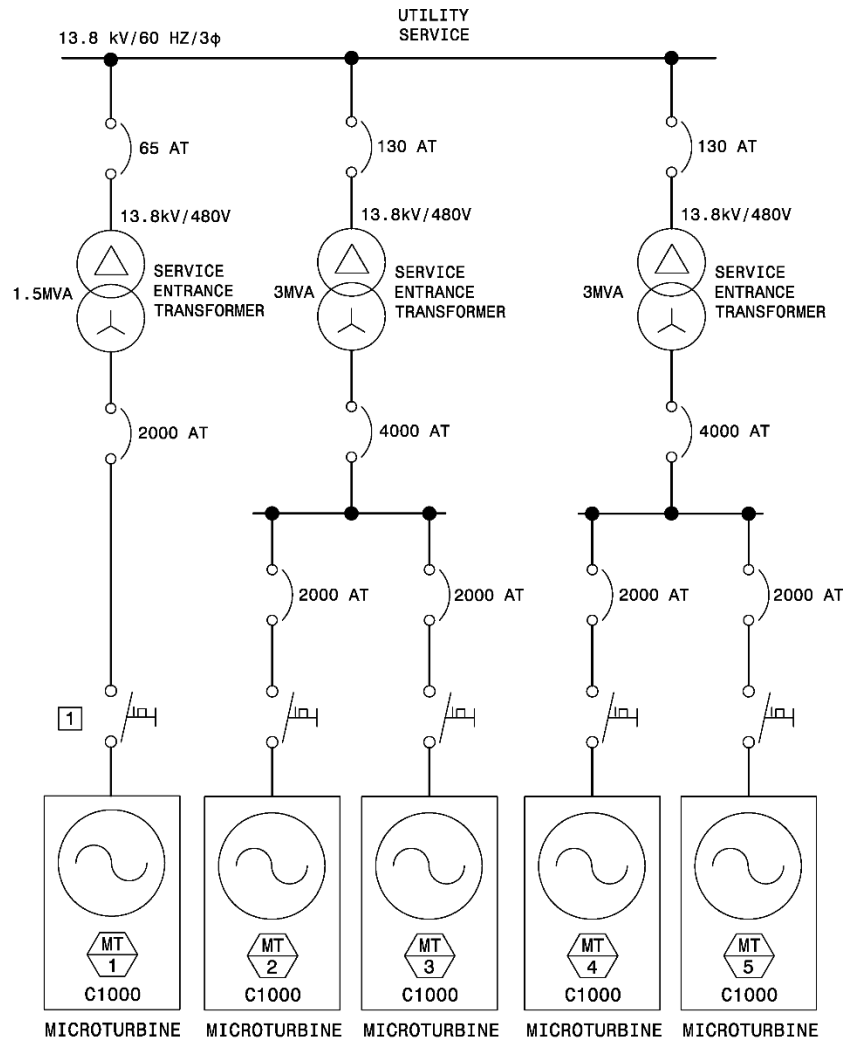
**Figure 39. One to Three Microturbines**





1 LOCKABLE DISCONNECT VISIBLE FROM EACH MT MAY BE REQUIRED BY LOCAL CODE

**Figure 40. Four Microturbines**



1 LOCKABLE DISCONNECT VISIBLE FROM EACH MT MAY BE REQUIRED BY LOCAL CODE

**Figure 41. Five Microturbines**

## 7.6. Standalone Mode

### 7.6.1. Overview

In Stand Alone mode, the turbine solely supports the load, providing required voltage, and active and reactive power. A microturbine in Stand Alone mode will try to maintain its pre-set voltage, regardless of connected loads. If the load is above the capability of the engine to provide continuous power, the batteries in the microturbine will supply the shortfall in an attempt to keep the system running. If this overload condition continues, the batteries will ultimately be drained and the system will eventually shut down. Therefore, it is important to size loads according to the guidelines detailed in the C1000S/C800S/C600S Technical Reference (Table 1).

### 7.6.2. Stand Alone Cyclic Loads

When operating in Stand Alone, special attention must be given to the frequency and magnitude of cyclic loads. When the microturbine operates in SA mode, the battery provides and absorbs instantaneous load variations. In order to extend battery life, the frequency and magnitude of the load cycles should be kept to a minimum. As a general rule, always consult with Applications if the load varies more than 20% of the capacity of a single microturbine every 10 minutes or less. Below are some examples of cyclic loads.

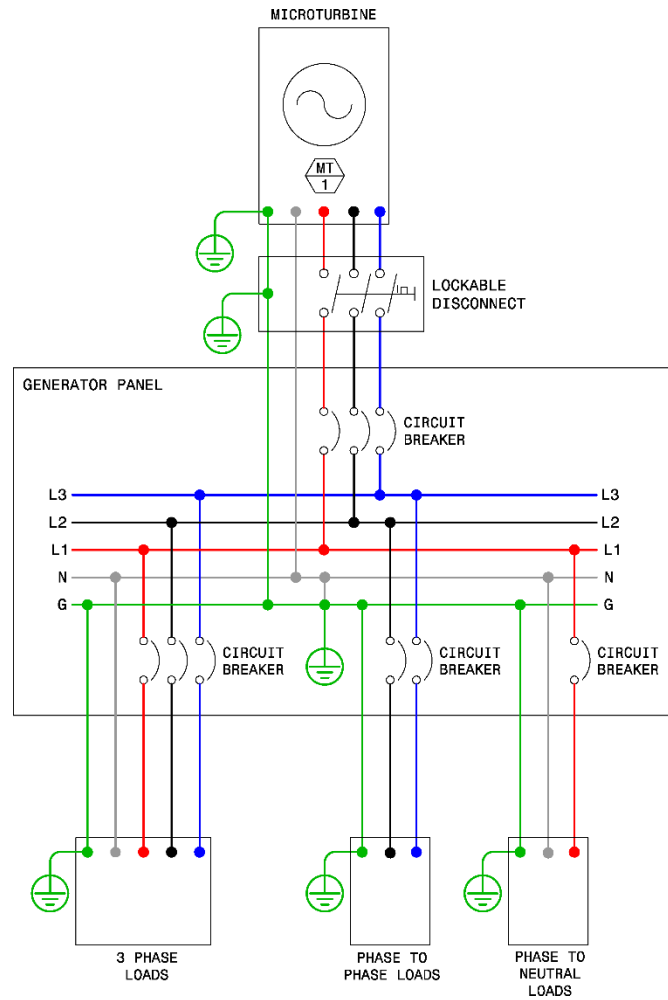
- Jack pumps or other type of rod pumps. These types of pumps typically have extreme load fluctuations, several times per minute.
- Large electric heaters modulated by SCRs. Most SCR-controlled heater systems cycle on/off several times per second.
- Large air compressors starting and stopping frequently.
- Large freight or personnel elevators.
- Large electric furnaces.
- Large electric commercial and industrial kitchens.
- Large electric tankless water heaters.
- Large water pumps cycling on/off.
- Electrical pumps driving hydraulic equipment.
- Pumps for large hydro-pneumatic tanks.

Please refer to the C200R Technical Reference (Table 1) for estimating battery life based on ambient temperature, as well as magnitude and frequency of load cycles. Always consult with Capstone if an important percentage of the load types are cyclic loads.

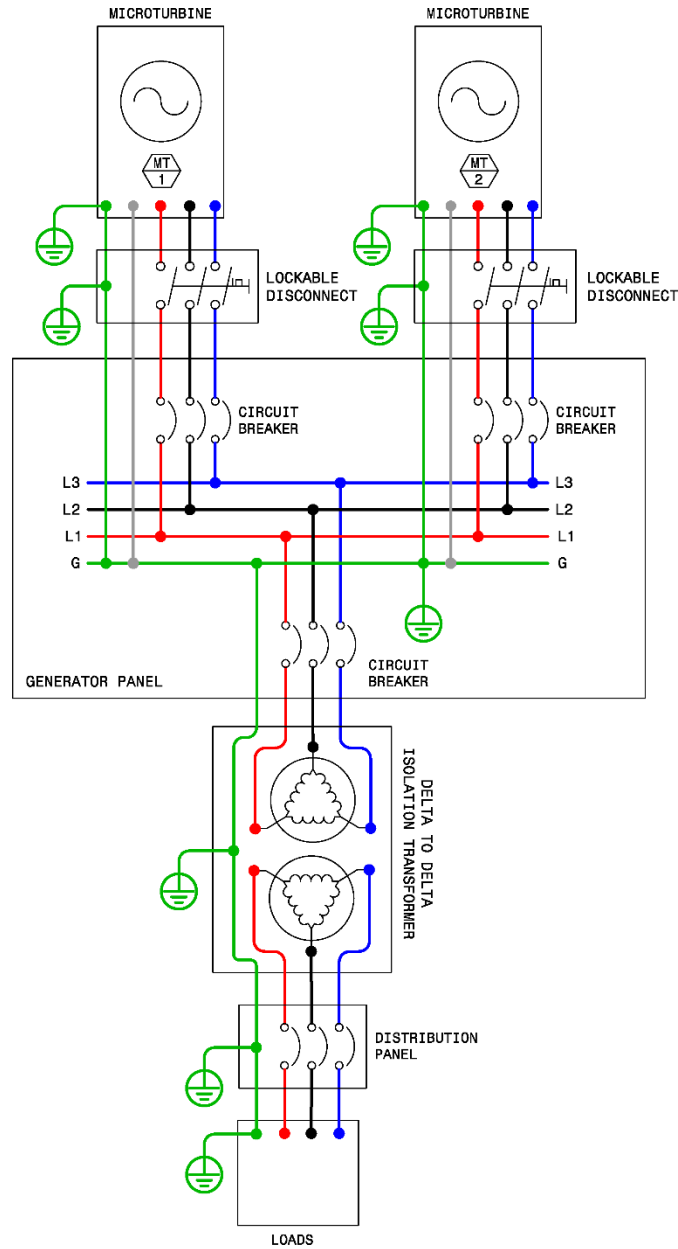
### 7.6.3. Stand Alone Connections

#### 7.6.3.1. Stand Alone Allowable Configurations

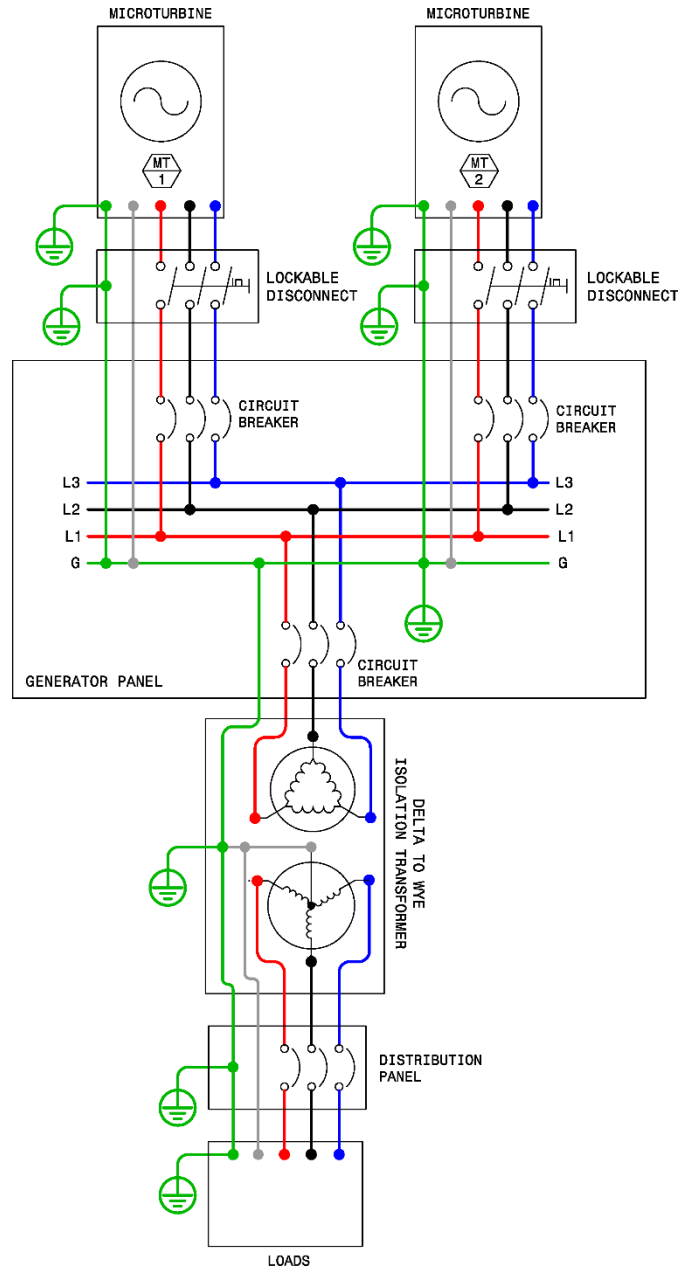
See Figure 43 through Figure 46 for examples of allowable microturbine Stand Alone connections for multiple microturbines.



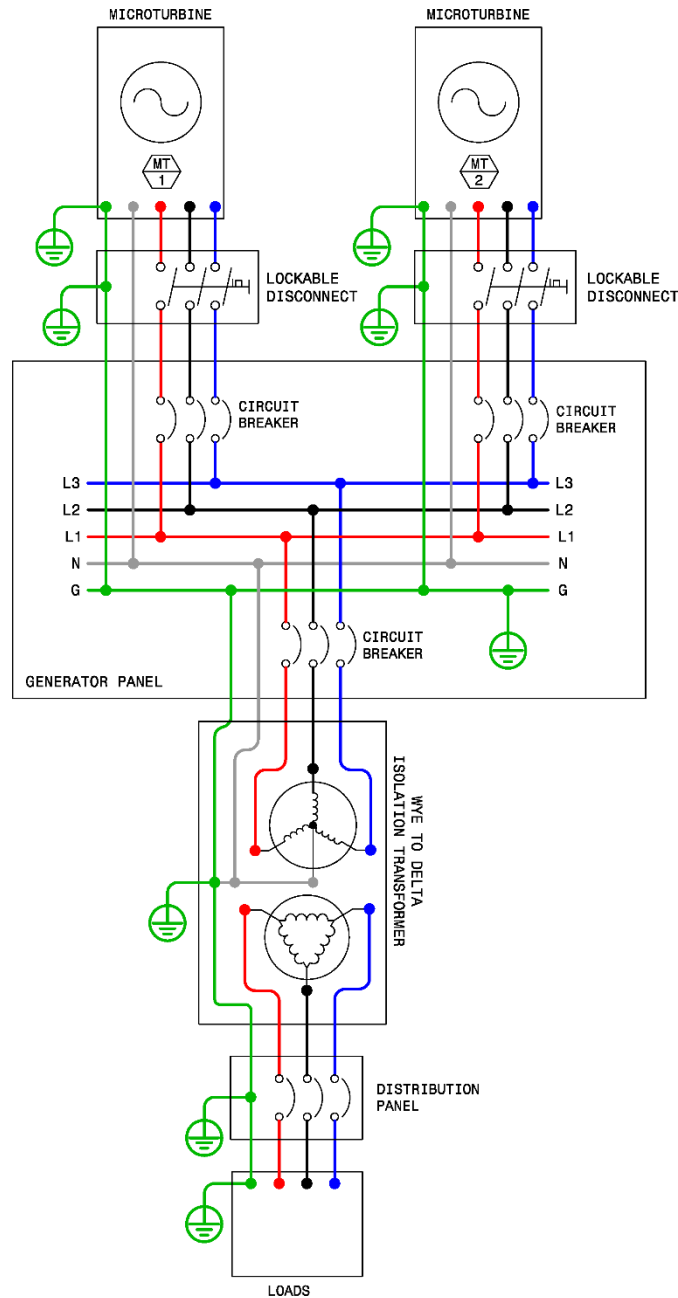
**Figure 42. Stand Alone Load Configuration**



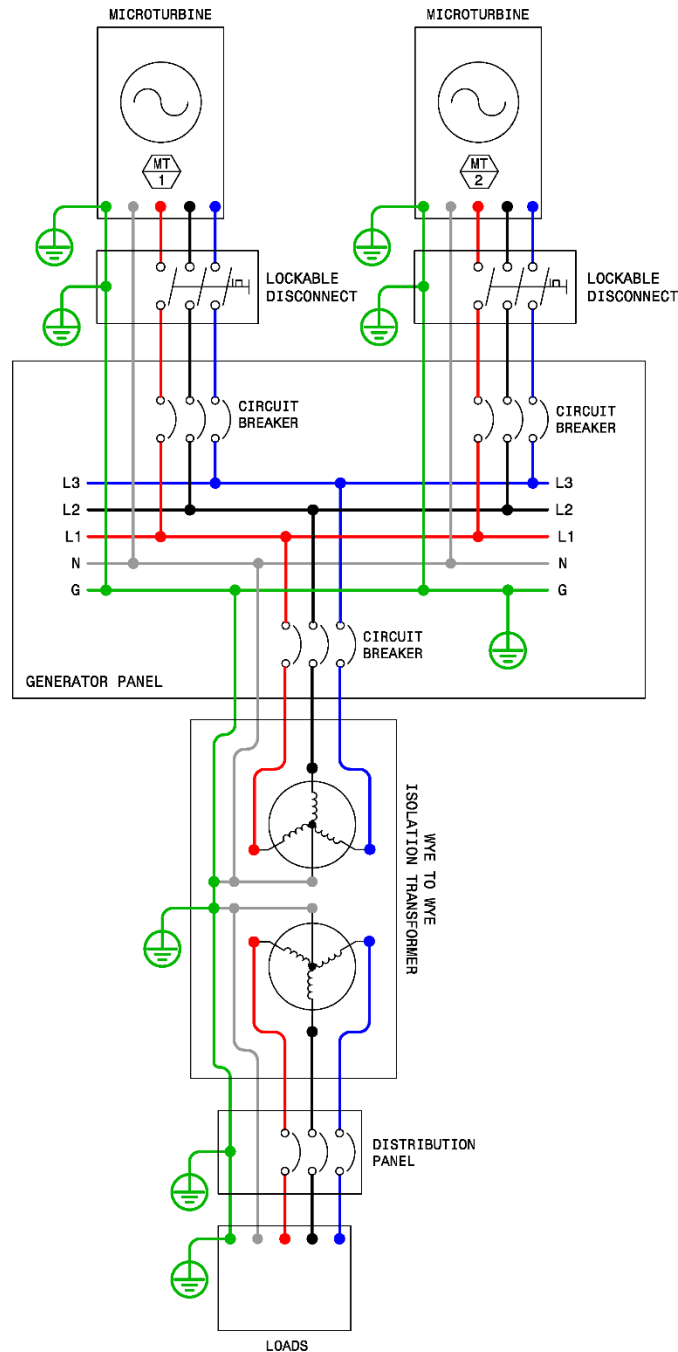
**Figure 43. Delta/Delta Isolation Transformer**



**Figure 44. Delta/Wye Isolation Transformer**



**Figure 45. Wye/Delta Isolation Transformer**

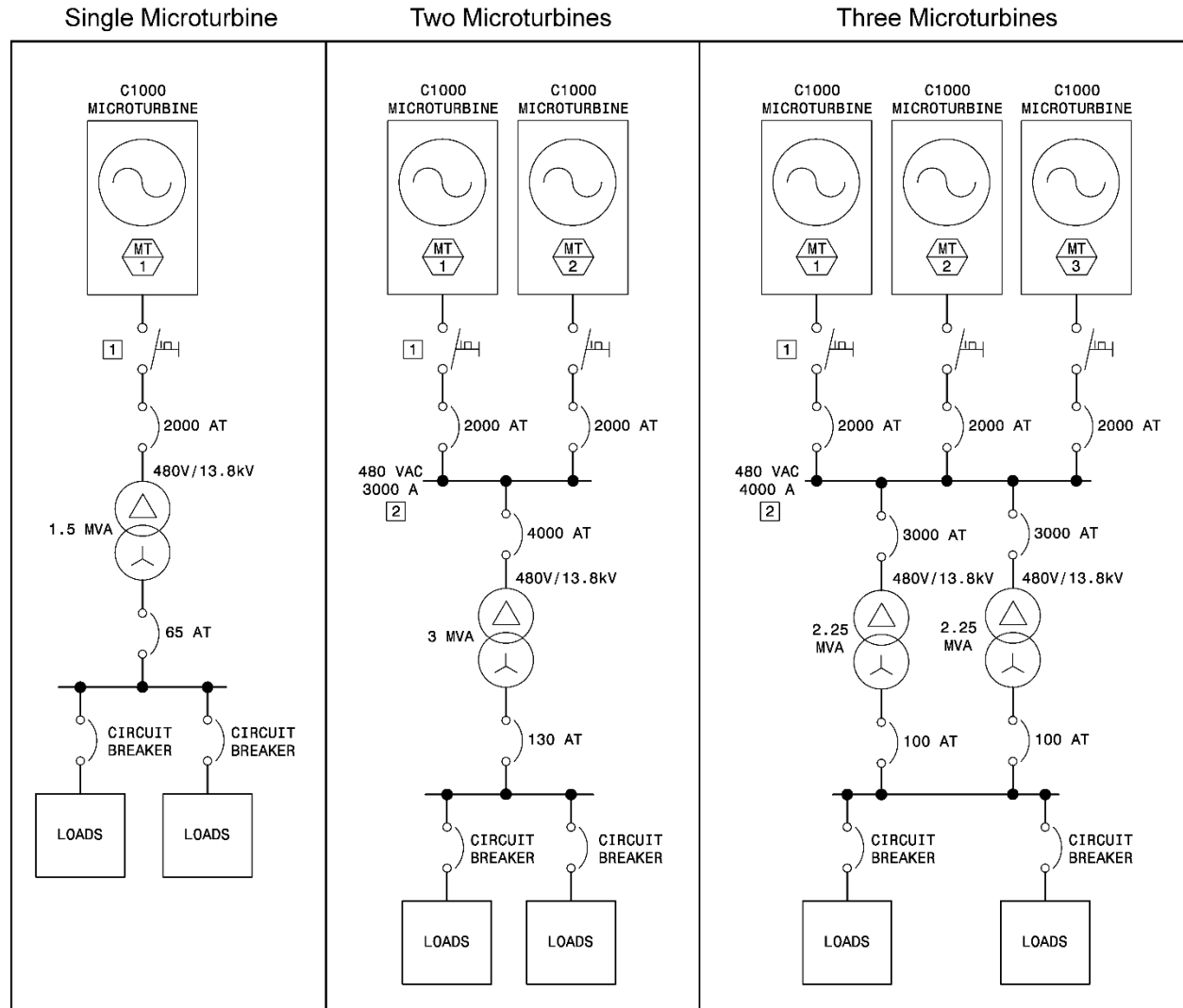


**Figure 46. Wye/Wye Isolation Transformer**



### 7.6.3.2. Examples of Single Line Diagrams

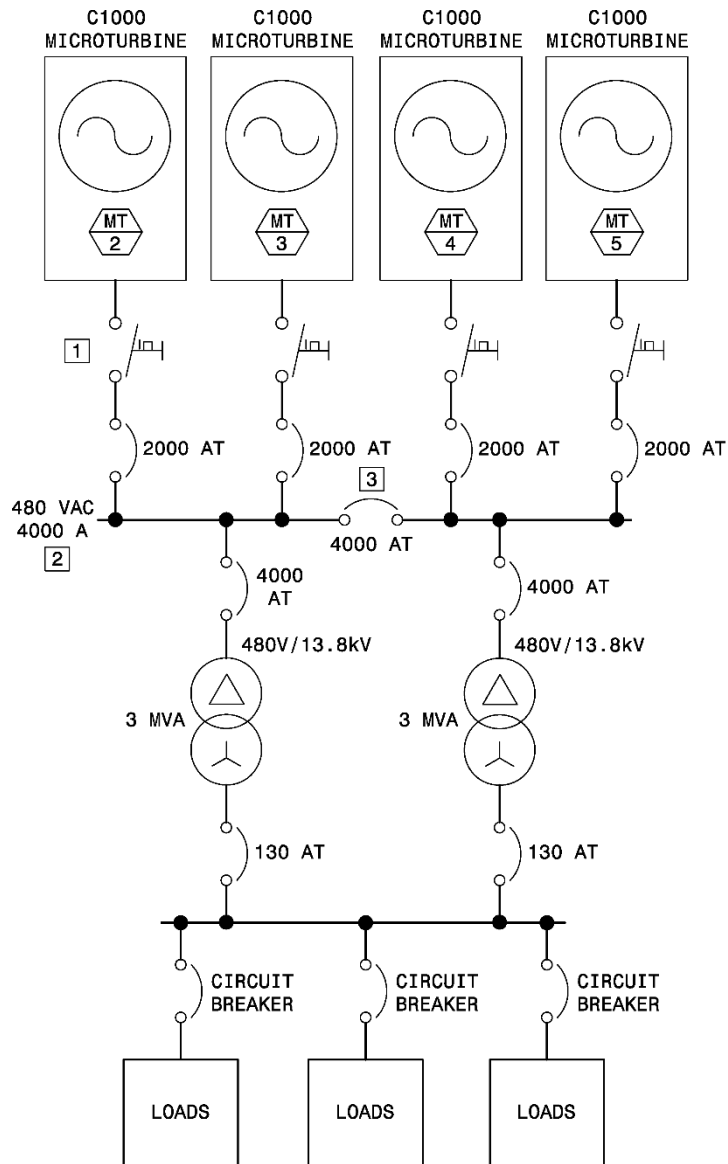
See Figure 47 through Figure 49 for Stand Alone installation single line diagrams.



1 LOCKABLE DISCONNECT VISIBLE FROM EACH MT MAY BE REQUIRED BY LOCAL CODE

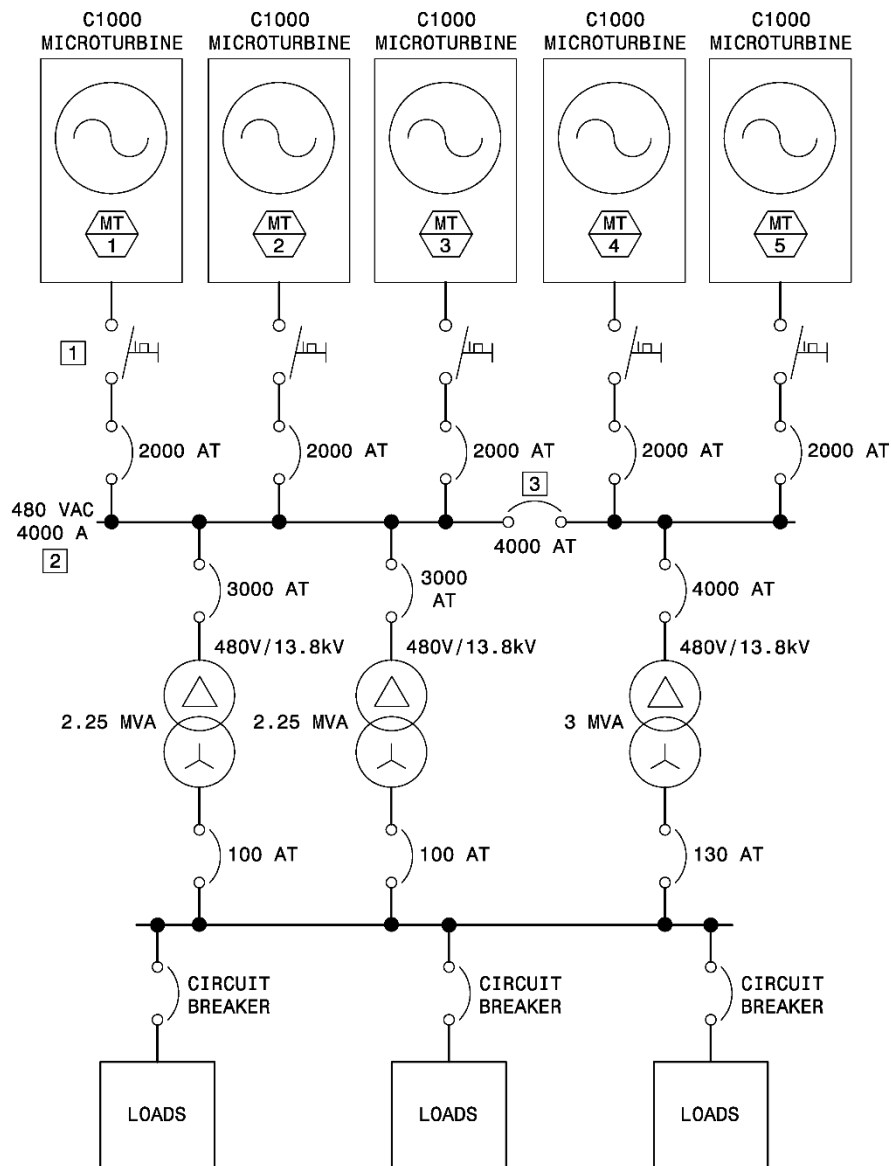
2 FOR SA OPERATION, MTs MUST ALL BE PARALLELED ON A SOLID BUS.  
 PARALLELING MTs THROUGH TRANSFORMERS IS NOT ALLOWED

Figure 47. One to Three Microturbines



- 1 LOCKABLE DISCONNECT VISIBLE FROM EACH MT MAY BE REQUIRED BY LOCAL CODE
- 2 FOR SA OPERATION, MTs MUST ALL BE PARALLELED ON A SOLID BUS. PARALLELING MTs THROUGH TRANSFORMERS IS NOT ALLOWED
- 3 TIE BREAKER MUST BE CLOSED WHENEVER MICROTURBINES ARE OPERATING ON BOTH SIDES.

**Figure 48. Four Microturbines**




- 1 LOCKABLE DISCONNECT VISIBLE FROM EACH MT MAY BE REQUIRED BY LOCAL CODE
- 2 FOR SA OPERATION, MTs MUST ALL BE PARALLELED ON A SOLID BUS.  
PARALLELING MTs THROUGH TRANSFORMERS IS NOT ALLOWED
- 3 TIE BREAKER MUST BE CLOSED WHENEVER MICROTURBINES ARE OPERATING  
ON BOTH SIDES.

**Figure 49. Five Microturbines**

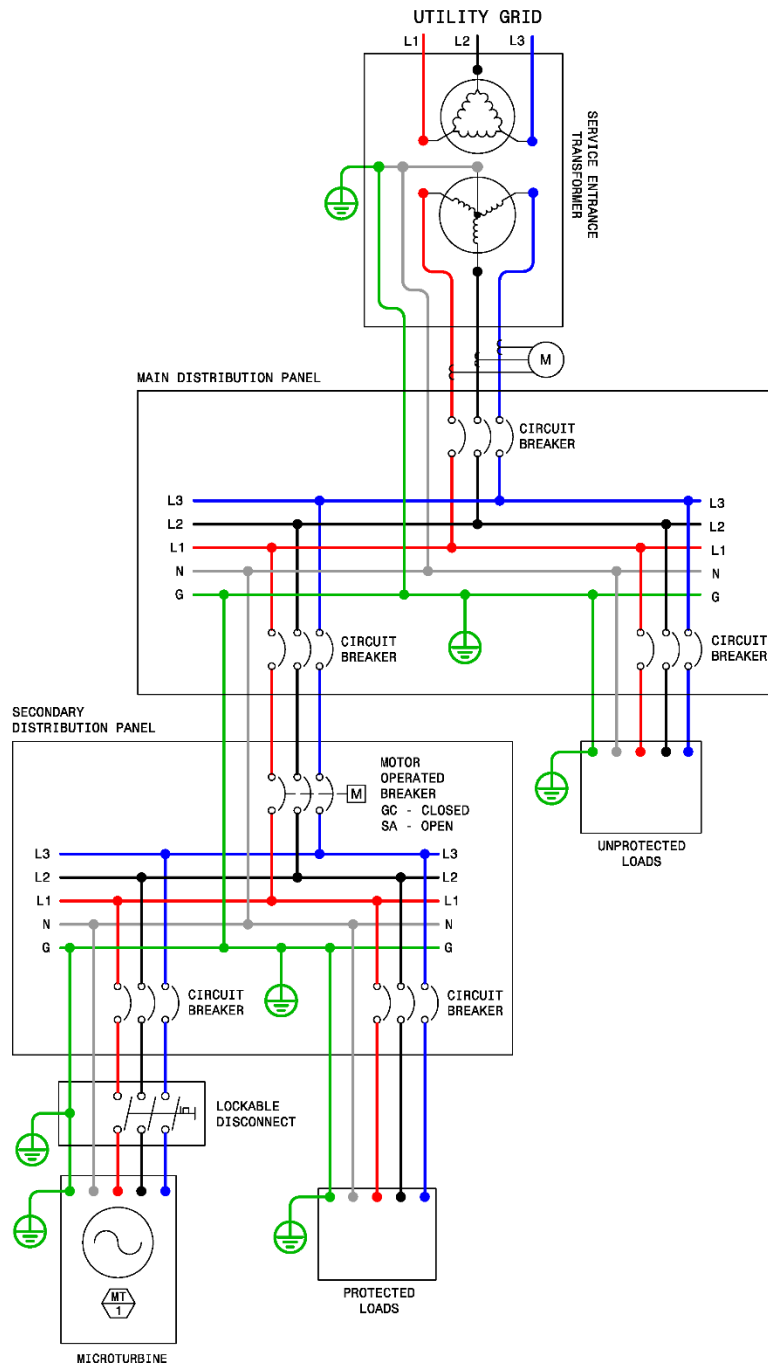
## 7.7. Dual Mode

An installation designed to switch between Grid Connect and Stand Alone operation is identified as Dual Mode, and must meet the installation requirements for both Grid Connect and Stand Alone operation. Automatic transfer between modes are accomplished with the Capstone Dual Mode System Controller (DMSC). Refer to the Dual Mode System Controller Technical Reference (Table 1) for details.

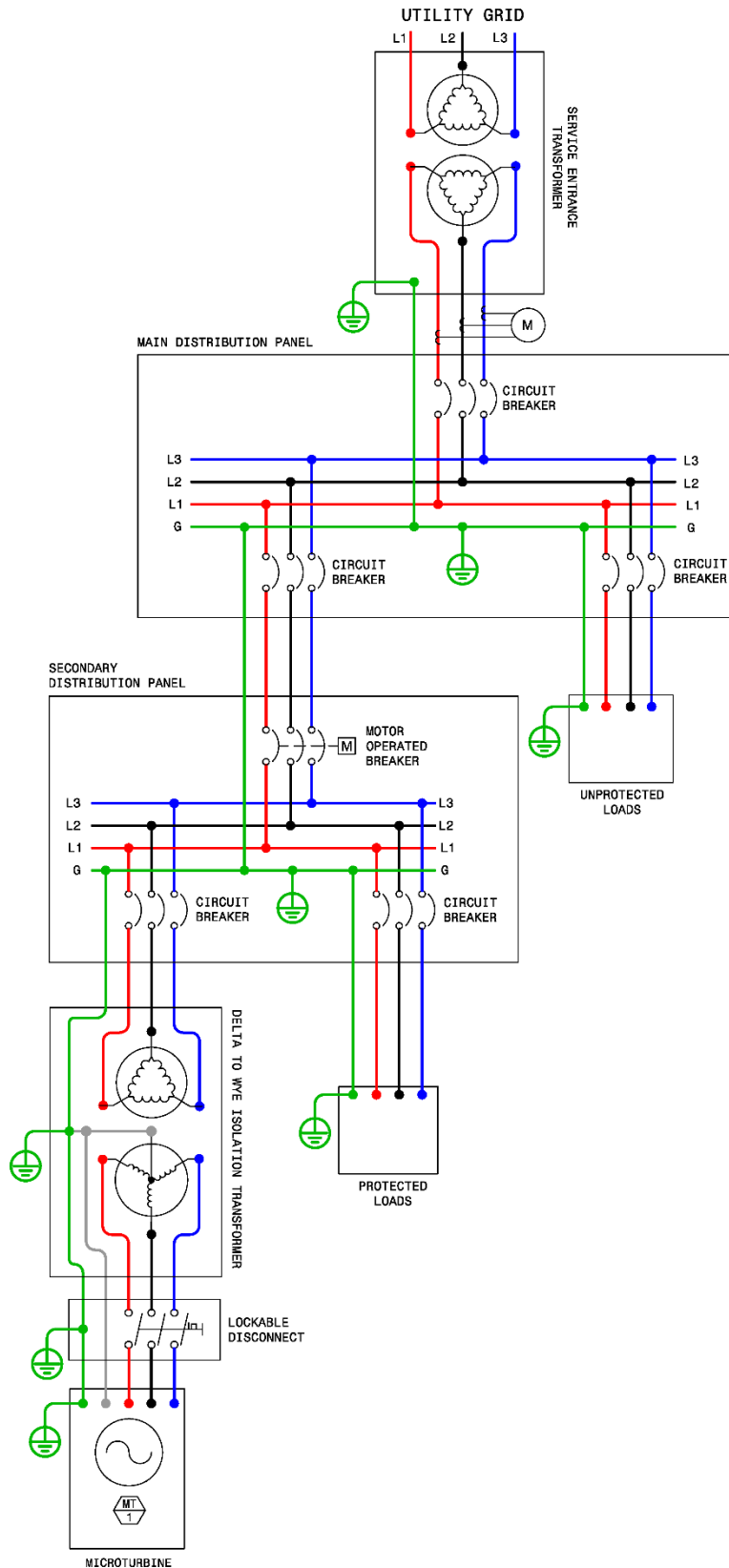
	NOTE
	<p>Some locations (generally where CE systems are used), require 4-pole circuit breakers, and a 4-pole motor-operated breaker, which will break the neutral wire as well as the three phases. The microturbine's neutral must be grounded at all times in both Grid Connect and Stand Alone modes. Therefore, a neutral-grounding relay, capable of keeping the neutral grounded when the DMSC switches the motor-operated breaker open, is required. This construction and theory of operation is discussed in the Dual Mode System Controller Technical Reference (Table 1).</p>

### 7.7.1. Dual Mode Connections

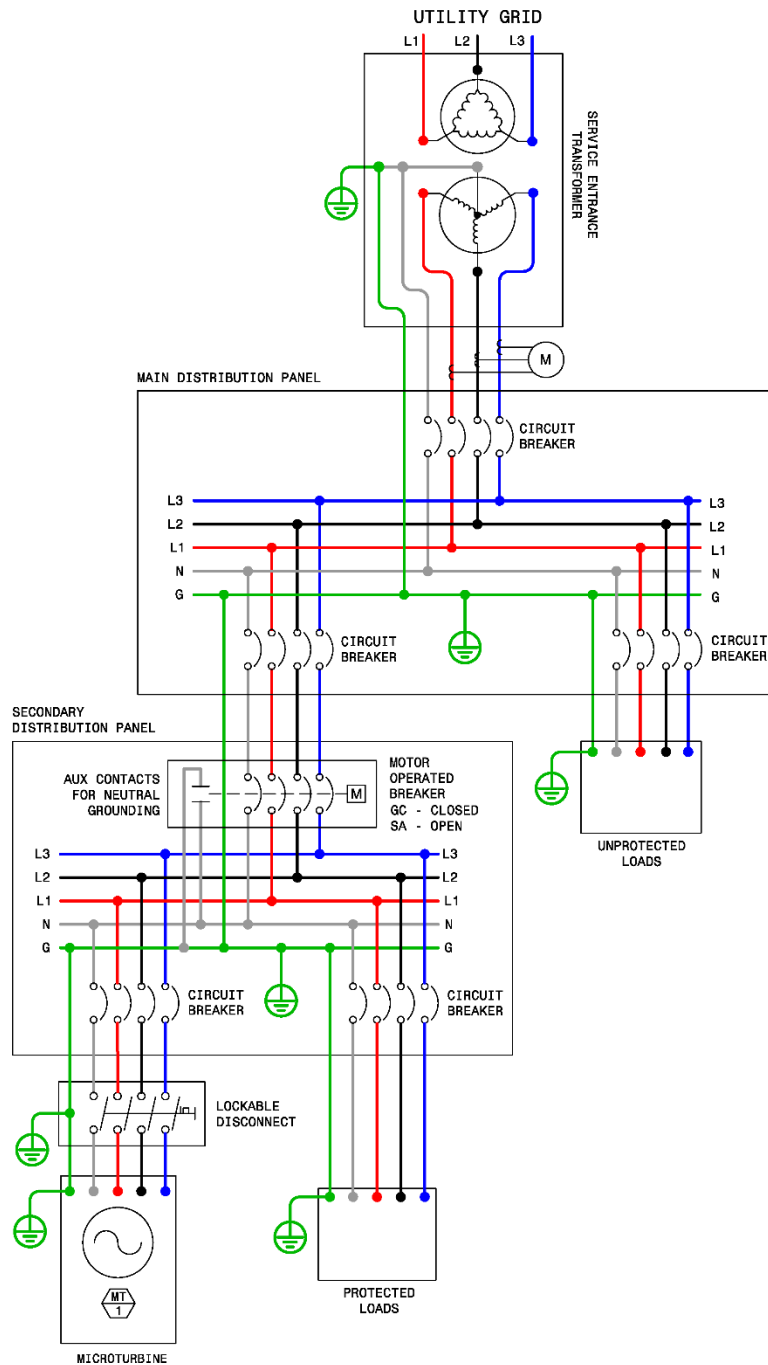
See Figure 50 through Figure 51 for allowable dual modes connections. The DMSC controls the motor-operated breaker which isolates the microturbines from the grid and protected loads.



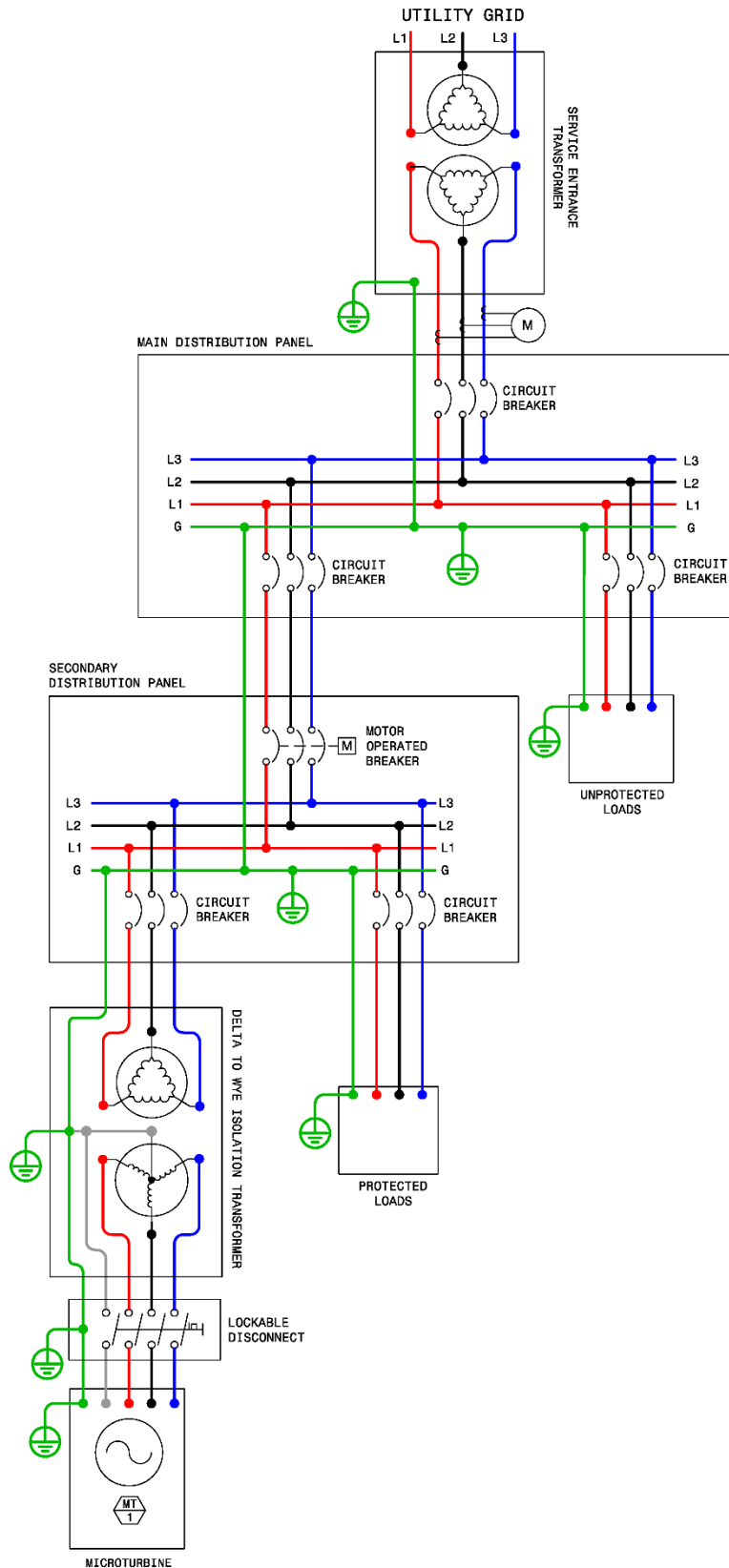
**Figure 50. Wye Service with 3-Pole Breaker**



**Figure 51. Delta Service with Delta/Wye Isolation Transformer and 3-Pole Breaker**



**Figure 52. Wye Service with 4-Pole Breaker**



**Figure 53. Delta Service with Delta/Wye Isolation Transformer and 4-Pole Disconnect**




## 7.8. Harmonics

It is important to keep harmonic levels to a minimum in any electrical installation. In addition to potential damage to customer equipment, high harmonic loads can increase stress on EMI filters in the microturbine, whether operating in Grid Connect or Stand Alone mode. In Stand Alone mode, current harmonic distortion can overheat and significantly reduce the life of microturbine batteries, IGBTs and other high power components.

### 7.8.1. Measuring Harmonics

It is recommended that a power quality study be performed on all installations, both for Stand Alone and Grid Connect operation, so that potentially costly challenges associated with harmonics can be avoided during the life of the project. A power quality study is performed using a power quality meter, which is a tool that measures voltages and currents on a three-phase electrical system with built-in calculations and graphing functions to explore subjects such as harmonic distortion, inrush currents, flicker, and others. This tool is sold by a number of electrical instrument companies, and can be rented temporarily in some parts of the world.

	<p style="text-align: center;"><b>CAUTION</b></p> <p>Voltage total harmonic distortion (THD) of 5% or greater in Grid Connect operation, and current THD of 8% or greater in Stand Alone operation, will damage microturbine hardware.</p>
---	--

#### 7.8.1.1. Grid Connect

For Grid Connect projects, the power quality meter can verify the voltage total harmonic distortion (THD) of the existing site, which should be below 5%, as specified by IEEE 519. If the voltage THD exceeds 5%, this will damage the microturbine hardware. High voltage harmonics can be caused by large non-linear loads on the same circuit, which may not even be located in the same facility, or by weak grids. Support from the local utility may be required.

#### 7.8.1.2. Stand Alone

For Stand Alone projects, the power quality meter can verify the current THD of the existing site, which should be below 8% to meet Capstone requirements. If the current THD exceeds 8%, this will damage the microturbine hardware. In addition, the high current THD will lead to degradation in site power quality (voltage THD), due to a positive feedback effect on the inverter controls, which may be perceived as voltage “flicker”. High current harmonics are created by switch mode power electronics devices such as:

- Variable Frequency Drives (VFD) / Variable Speed Drives (VSD)
- Uninterruptible Power Supplies (UPS)
- Heaters with thyristors, or Silicone Controlled Rectifiers (SCR)
- Fluorescent ballasts and sodium lamps

### 7.8.2. Mitigating Harmonics

Below is a list of recommendations to reduce harmonic levels. Always consult with Capstone whenever high harmonic loads represent a significant percentage of the total site load.

- When specifying a VFD, always select IGBT-based VFDs with Active Front End power inputs. If IGBT-based VFDs are not possible, select 18- or 24-pulse VFDs. Many VFD manufacturers offer accessories for their VFDs to reduce harmonics, including in-line chokes. Always select the VFD and accessories that offer the lowest current harmonics at the input of the VFD.
- The use of a transformer with a Delta winding on the microturbine side will effectively filter out the third harmonic. It is recommended to always specify a transformer with a delta winding on the microturbine side for Stand Alone only applications. This is required for any Stand Alone installation with highly non-linear loads and current THD >8%. The isolation transformer reduces “triplen” harmonics, which are common with non-linear loads.<sup>1</sup> If the current THD at the microturbine is still reading above 8%, it is recommended to improve the “worst offender” loads contributing the most to the THD problem. If the microturbines will operate in Dual Mode with high harmonic loads, a transformer with a delta winding on the microturbine side of the transformer can still be used in combination with a grounding transformer on the delta circuit.

For example, if there is a large VFD that seems to be increasing the THD current when it is operating, installing an input line filter can reduce the harmonics. However, there are limits to this approach, especially for the lowest cost equipment using 6-pulse rectifier bridge inputs. No simple input filter can reduce the current THD of these devices to meet <8%. In this case, some combination of input line filters, and site-general isolation transformer, or possibly even a hardware upgrade to a 12- or 24-pulse rectifier bridge input VFD may be required. If these actions are not enough, a final option would be installation of a custom-designed electrical filter tuned to reduce the specific harmonics profile present on the site.

- Many manufacturers of UPSs and large battery chargers also offer different options to reduce current harmonics. As with the VFDs, always select IGBT-based UPSs with Active Front end. If IGBT-based UPSs are not available, select 18 or 24-pulse UPSs. Also make sure to include all options provided by manufacturer, such as in line chokes, to offer the lowest harmonic distortion in input current.
- For processes requiring large heaters (>10 kW) always specify gas-fired heaters or use heat recovery from the microturbine exhaust. Most large heaters are modulated with SCRs (also known as thyristors). These devices not only introduce high levels of harmonics, but also generate very frequent and large power cycles, which significantly shorten the microturbine battery life in SA operation.

Voltage and current harmonics of the load may have an increasing effect on the microturbine voltage and current harmonics due to their interaction with the output inverter of the microturbine. This interaction between the microturbine and load/grid harmonics can increase the steady-state level of voltage and current harmonics in the system.

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<sup>1</sup> Additionally, the transformer will improve voltage balance by cancelling zero sequence currents. It is highly recommended to specify the voltage of the transformer on the microturbine side to 480 VAC. This will allow operation with maximum available current for starting loads.

Harmonics cause an increase in eddy currents in the transformer core, which in turn increase heat in the transformer and may damage the insulation on windings, causing serious problems. With high current harmonics, a transformer may not have enough capacity for a specific load, even if the transformer capacity is sized for the load.

K-factor is a means to quantify the harmonic load currents and their heating effect on a transformer. A K-factor of 1.0 indicates a linear load (no harmonics); a higher K-factor value indicates a higher heating effect on the transformer.

Generally, only manufacturers of larger transformers (>1 MVA) will offer different K-factor ratings. Hence, it becomes important to oversize smaller transformers operating on non-linear loads. Most K-factor rated transformers are custom-built, so in some cases it is more economical to simply oversize the transformer.

- As a rule, the smallest transformer that should be tied to the output of a SA microturbine should not be smaller than 45 kVA, even if the connected load is much smaller.
- When powering high harmonic loads (>8% THD in current), the transformer should be oversized by 40% at a minimum.

If specifying the K-factor of the transformer is possible, a K-factor between 9 and 13 is recommended for loads with high harmonics (>8% THD in current). Even with an oversized transformer or a transformer with a high K rating, it is highly recommended to always keep the load harmonics to a minimum.

## 8. Communication

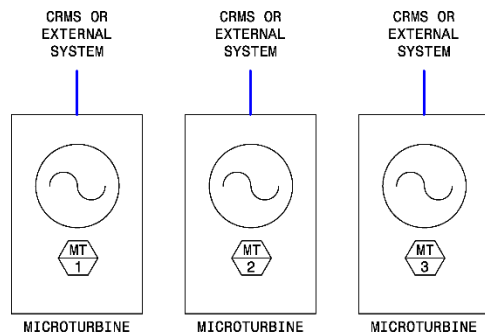
### 8.1. Ethernet Communication

Communication and control for Capstone microturbines is made to a single microturbine or to a group of microturbines, as shown in Figure 54. External connections are made to the C1000 series controller in the EPDB (see Figure 12). Refer to the C1000S/C800S/C600S Technical Reference (Table 1) for a detailed description of all C1000 series controller connections. For multiple units a Capstone Logic Controller (CLC) must be used.

To use CRMS, refer to the CRMS Maintenance Edition Technical Reference (Table 1) and connect a PC to the C1000 series controller as follows:

1. Connect a Cat 5/Cat 6 cable between the PC Ethernet port and the external Ethernet connector on the C1000 series controller. Use CRMS to establish communication with the controller.
2. Use CRMS to establish a TCP/IP connection with the controller.

#### Individual Microturbines (No MultiPac)



#### Capstone Logic Controller as MultiPac Master

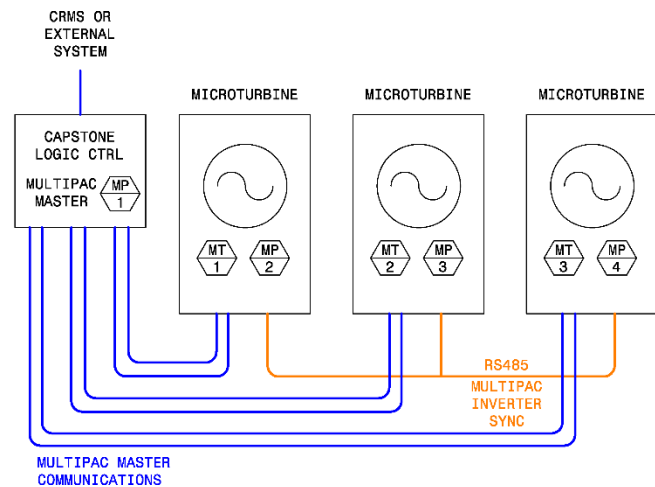



Figure 54. Communication and Control Overview

## 8.2. C1000 Series Controller TB1 Connections

External connections made to terminal block TB1 are described in the following paragraphs.

### 8.2.1. Emergency Stop

	<div data-bbox="836 394 971 445" data-label="Section-Header"><h4>NOTE</h4></div> <p>At least one emergency stop device must be connected to the microturbine to enable averting actual or impending danger. When installed at a facility, the emergency stop device must be clearly identifiable, clearly visible, and quickly accessible.</p> <p>For CE-compliant installations, the disconnect device must be IEC approved and installed at an approved height.</p>
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At least one emergency stop device must be connected to the microturbine to enable averting actual or impending danger. When installed at a facility, the emergency stop device must be clearly identifiable, clearly visible, and quickly accessible.

#### 8.2.1.1. E-Stop Requirements

The emergency stop device must have direct opening operation per IEC 60947-5-1, and must be one of the following types:

- Push-button operated switch with palm or mushroom head
- Pull-cord operated switch
- Pedal operated switch without a mechanical guard

The color of the device actuator must be red. If there is any background immediately around the actuator, the color of the background must be yellow.


The performance characteristics must be as follows:

- The device must stop the microturbine as quickly as possible without creating additional risks.
- Where necessary, the device must trigger or permit the triggering of certain safeguard movements.
- After a stop command, once active operation of the device has ceased, the stop command must be sustained by engagement of the device until that engagement is specifically overridden.
- It must not be possible to engage the device without triggering a stop command.
- The device must be disengaged only by an appropriate operation; and disengaging the device must not restart the microturbine but only permit restarting.

Always refer to the latest national and local codes relative to your location to determine the proper connection requirements. Refer to the C1000S/C800S/C600S Technical Reference (Table 1) for details about E-Stop operation.

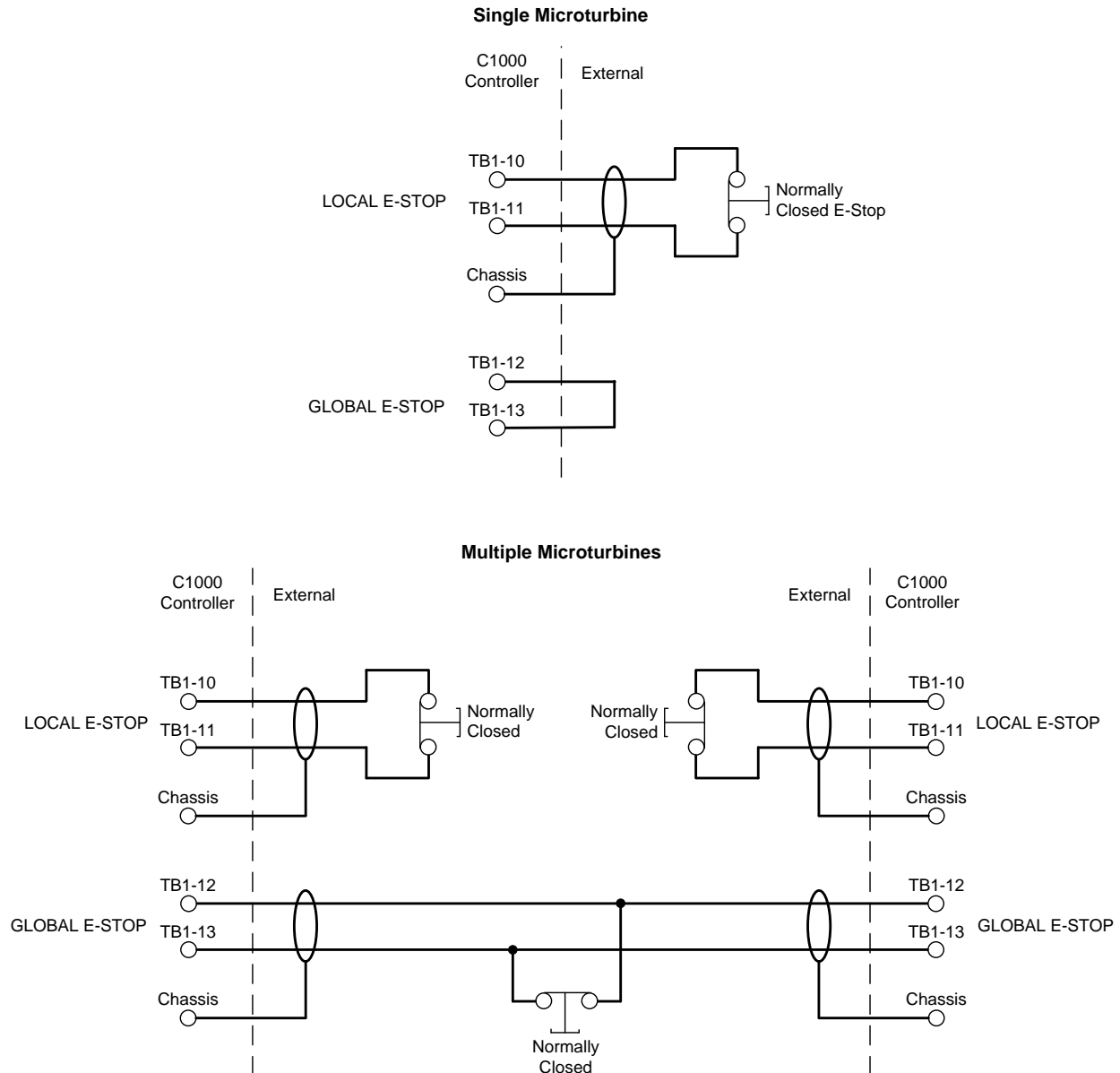
### 8.2.1.2. E-Stop Installation

The E-Stop inputs are identified as Local and Global E-Stops. This enables connection to a local E-Stop device for stopping a single C1000S/C800S/C600S assembly, and to a global E-Stop device for stopping multiple assemblies. The E-Stop inputs in a C1000 series controller are simple contact closures intended for dry contact circuits.

	<div data-bbox="836 422 980 468"><b>NOTE</b></div> <p data-bbox="407 506 1365 573">If no external E-Stop device is installed, the E-Stop pins on terminal block TB1 must be jumpered.</p>
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See Figure 55. The E-Stop configuration options are as follows:

- No E-Stop: Install jumper between local E-Stop terminals TB1-10 and TB1-11. Install jumper between global E-Stop terminals TB1-12 and TB1-13.
- Local E-Stop only: Install jumper between global E-Stop terminals TB1-12 and TB1-13, and connect an E-Stop device to the local E-Stop pins TB1-10 and TB1-11.
- Global E-Stop only (MultiPac configuration): Install jumper between local E-Stop terminals TB1-10 and TB1-11, and connect an E-Stop device to global E-Stop terminals TB1-12 and TB1-13. Wire the global E-Stop pins from one C1000 series controller to the next in the MultiPac.
- Local and Global E-Stop (MultiPac configuration): Remove jumpers and connect a local E-Stop device and global E-Stop device to their respective TB1 pins. Wire the global E-Stop pins from one C1000 series controller to the next in the MultiPac.



**Figure 55. E-Stop Connections**

### 8.2.2. Multiple Microturbine (RS485) Connections

The required RS485 connections between multiple microturbines are shown in Figure 56. This is done to continue the inverter sync signal from one turbine assembly to the next. Within a single C600S, C800S, or C1000S assembly, the inverter sync signal is communicated via standard MultiPac cables connected between turbine bays. When multiple units are connected together, the signal must be continued from the last bay in one unit to the first bay in the next unit. Jumpers are installed to terminate each end of the RS485 cable series, and the jumpers must be removed at the point of connection. Refer to Table 15 for the external RS485 connections at terminal block TB1. Refer to the C1000 MultiPac Sync drawing (Table 1) for a detailed description of the internal and external RS485 connections.

**Table 15. External RS485 Connections at TB1**

TB1 Connections	First Unit in Series	Middle Unit	Last Unit in Series
TB1-14	Jumper Installed	Jumper Removed	Jumper Removed
TB1-15			
TB1-25	Jumper Installed	Jumper Removed	Jumper Removed
TB1-26			
TB1-27	Jumper Installed	Jumper Removed	Jumper Removed
TB1-28			
TB1-29	Jumper Removed	Jumper Removed	Jumper Installed
TB1-30			
TB1-40	Jumper Removed	Jumper Removed	Jumper Installed
TB1-41			
TB1-42	Jumper Removed	Jumper Removed	Jumper Installed
TB1-43			
TB1-44	No Connection	RS485-A	RS485-A
TB1-45	No Connection	RS485-B	RS485-B
TB1-46	No Connection	Chassis Ground	Chassis Ground
TB1-48	RS485-A	RS485-A	No Connection
TB1-49	RS485-B	RS485-B	No Connection



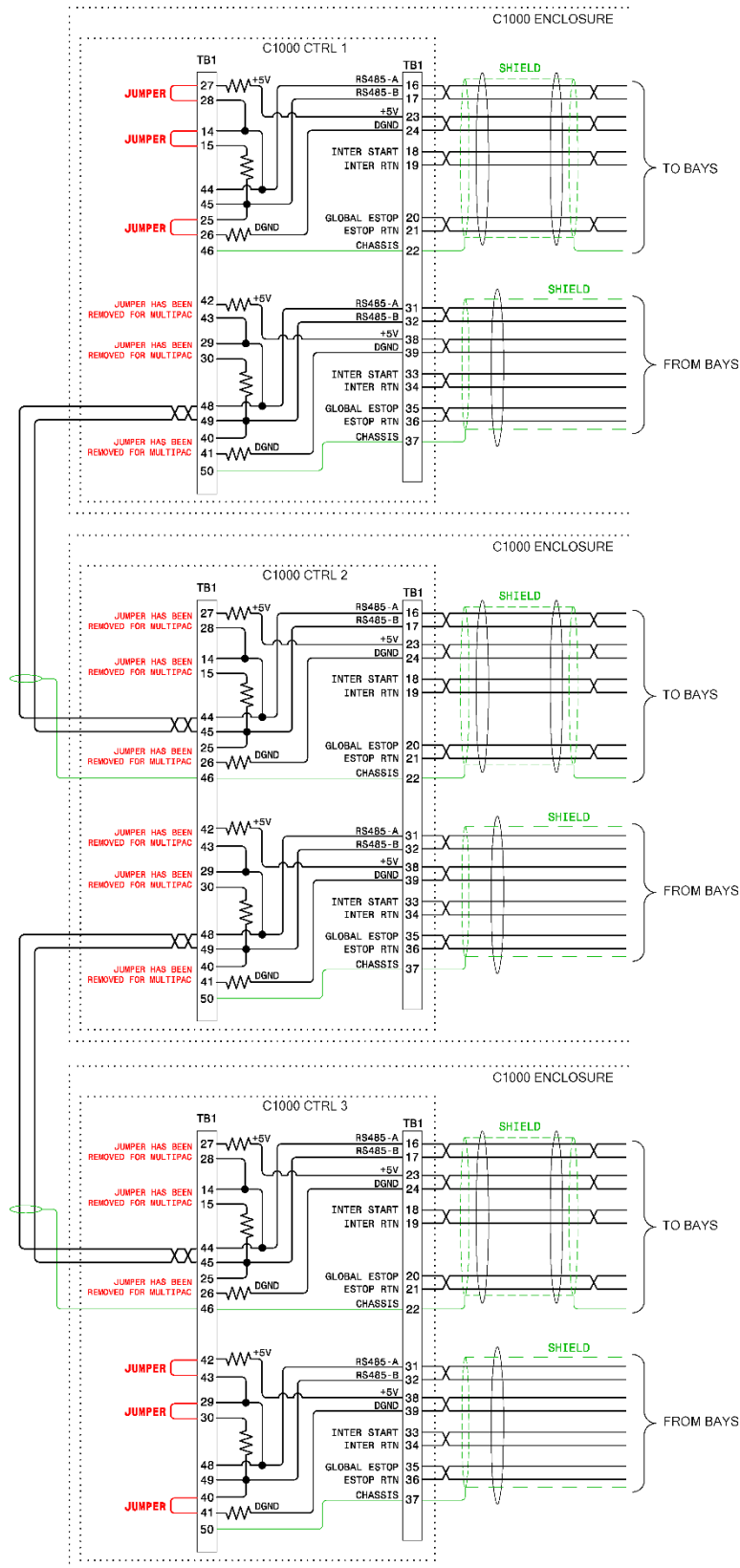
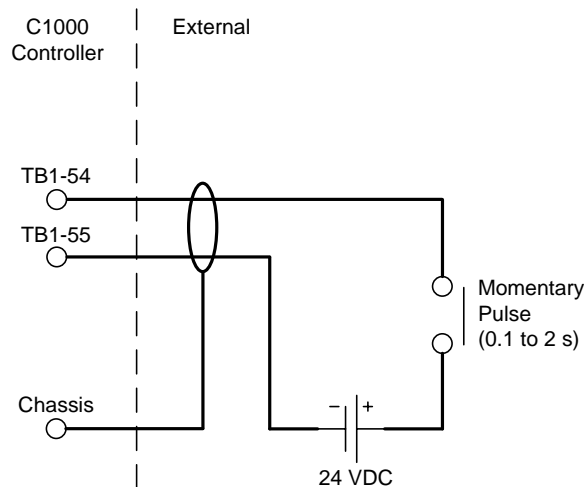


Figure 56. Multiple Microturbine (RS-485) Connections

### 8.2.3. Battery Wakeup Connections

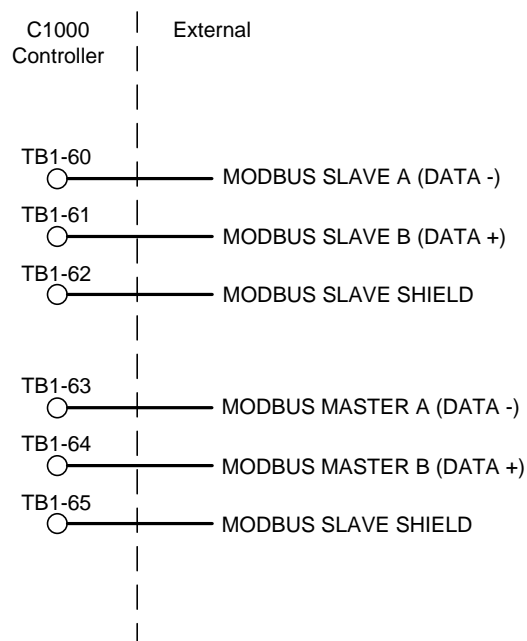
A Stand Alone capable (battery-equipped) microturbine enters sleep mode to conserve battery power during prolonged periods of inactivity. A 24 V external contact that provides a momentary pulse can be used to wake up the microturbine from sleep mode. See Figure 57 for an example battery wakeup connection to the C1000 series controller. Connect the +24 V side of the contact to TB1-54 and 0 V to TB1-55.



**Figure 57. Battery Wakeup Connection**

### 8.2.4. Modbus

Communication with an individual microturbine via Modbus is available at terminal block TB1 in the C1000 series controller. See Figure 58 for Modbus connections. Refer to the C1000S/C800S/C600S Technical Reference (Table 1) for details.



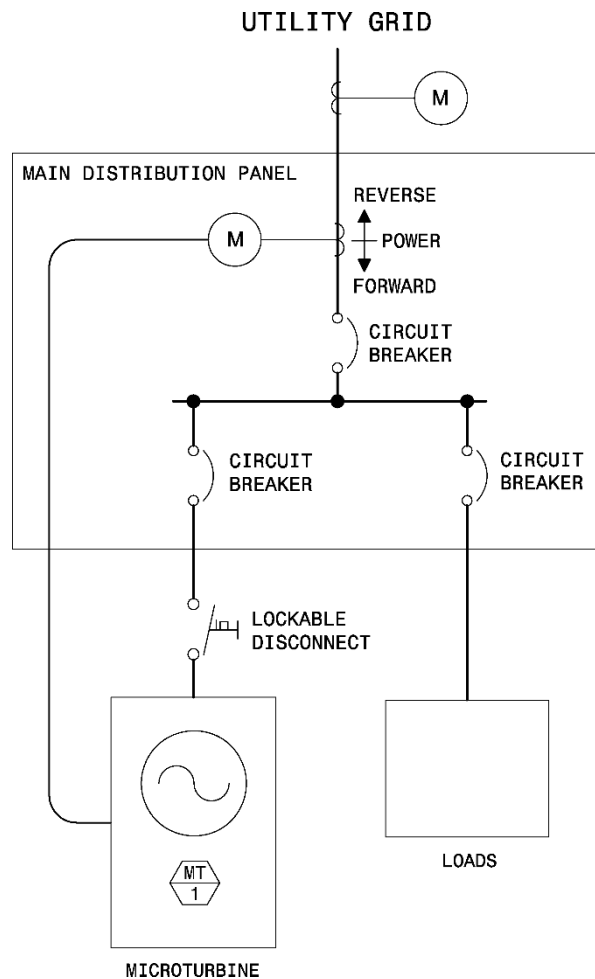
**Figure 58. Modbus Connections**

#### 8.2.4.1. Power Meter Applications

In Grid Connect applications with variable electric loads, a utility may restrict power exporting. These restrictions can be adhered to using non-power export mode or limited power export mode. The microturbine can accommodate pulse inputs for forward power flow (+PWR) and reverse power flow (-PWR) signals at a rate proportional to the power flow to control power produced. The microturbine ramps power output up and down, keeping the required power level at the control point.

Consideration should be given to meters approved by the utility company for compatibility, when used at the PCC or any other point controlled by the utility, especially if used as a revenue meter for accounting purposes.

The C1000 series controller is designed to accept signals from a Modbus slave power meter using RS-485 wired to the PLC. See Figure 58 for Modbus slave connections (TB1-60, TB1-61, TB1-62) in the C1000 series controller, and Figure 59 for a typical power meter installation.



**Figure 59. Typical Power Meter Installation**

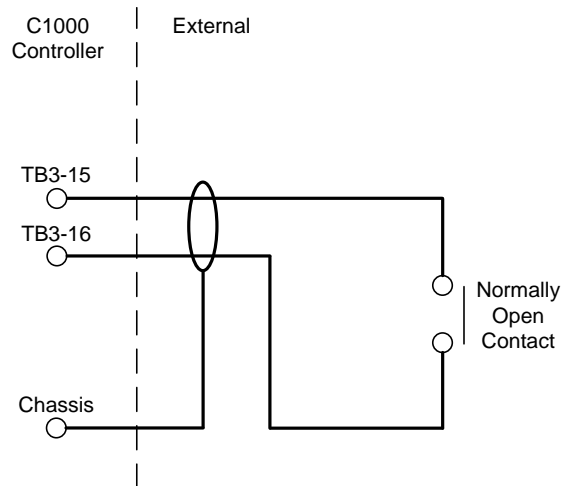
## 8.3. C1000 Series Controller TB3 Connections

External connections made to terminal block TB3 are described in the following paragraphs.

### 8.3.1. Remote Start/Stop

The Start/Stop signal, sometimes called the Start Enable signal, is a configurable hard-wire control system interlock that provides a permissive for a C1000S start command when true. If this start permissive is not present through hardwire, the unit will not start, and if the start permissive is removed during operation, the unit will shut down. The proper connections must be made in the C1000 series controller for the desired start/stop control function, and the User/Remote options must be selected from the External Input Dispatch function using CRMS software.

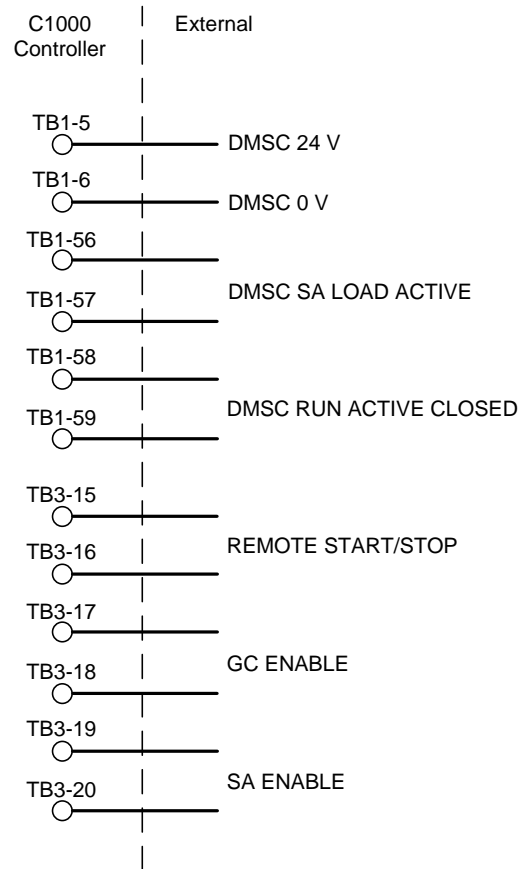
The remote Start/Stop input connection is wired terminal block contacts TB3-15 and TB3-16 (Figure 60). Closing an external contact will initiate a start, and opening this same contact will stop the turbine.



**Figure 60. Typical Remote Start/Stop Connection**

### 8.3.2. DMSC

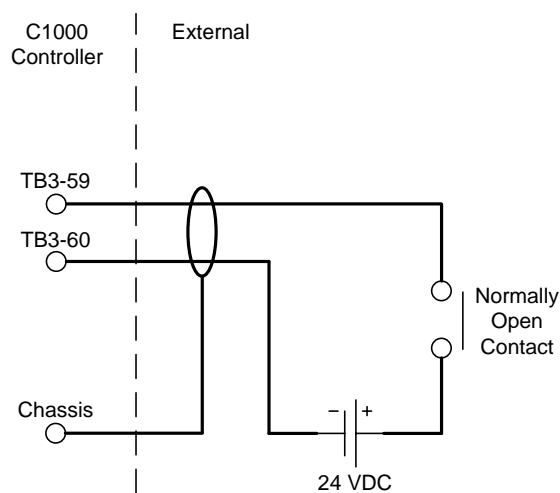
The Capstone Dual Mode System Controller (DMSC) is used to perform the automatic transfer between GC and SA modes in Dual Mode. Refer to Section 7.7. Terminal block contacts used for the DMSC are shown in Figure 61. Refer to the Dual Mode System Controller Technical Reference (Table 1) for wiring details.



**Figure 61. DMSC Terminal Block Connections**

### 8.3.3. Fault Inputs

See Figure 62 for an example fault input connection to the C1000 series controller. Connect the +24 V side of the contact to TB3-59 and 0 V to TB3-60.



**Figure 62. Fault Input Connections**

### 8.3.4. Fault Input

The C1000 series controller has a single fault input that is used to activate UCB Fault Input 2 in each microturbine bay. Refer to the C1000S/C800S/C600S Technical Reference (Table 1) for a detailed description of the internal wiring and operation of the fault input.

#### 8.3.4.1. Fault Input Settings

Refer to the CRMS Maintenance Edition Technical Reference (Table 1) and make the following settings for fault inputs:

- Enable/Disable (On/Off) – If On, control detects a fault input to the system from an external fault source.
- Fault Level defines the system severity level of this fault source.
  - Level 2 – Warning issued. Microturbine will continue to operate.
  - Level 3 – Standard microturbine shutdown sequence (cooldown).
  - Level 4 – Fast microturbine shutdown sequence (warmdown).
- Time (sec) – adjustable debounce time for fault input detection from an external device, i.e., how much time the fault is detected for before the fault is latched in the system.
- Active (Open / Close)
  - Active Open – If the fault input contact changes state from a closed position to an open position the fault is declared.
  - Active Close – If the fault input contact changes state from an open position to a closed position the fault is declared.
- Fault input 1 is used to shut down the microturbines in the event that the external fault device (normally closed) is activated. This change of state at relay R1 contacts is configured as Active Close in CRMS.
- Fault input 2 is used to shut down the microturbine in the event that the contact (normally open) is activated. This change of state is configured as Active Close in CRMS.

## 8.4. External Controller Connections

A Capstone Logic Controller (CLC) is used to connect multiple C1000S/C800S/C600S microturbines into a MultiPac, which can also include C200 microturbines. A CLC can also be connected to an individual microturbine when the customer application requires a remote control panel, custom graphics, or other features of the CLC. When connecting to a CLC, the C1000 series controller panel PC is disabled, and the CLC communicates directly to each C200 microturbine module within each microturbine. The CLC then becomes the MultiPac master and provides a single point of control for each individual microturbine module or separate C200 microturbine. The C1000S/C800S/C600S microturbines are pre-wired to simplify connection to a CLC, as described below (Figure 64).

#### **8.4.1. Dual Mode Connections to a CLC**

Dual Mode C1000 microturbines include a star communications topology for both MultiPac communications (10Base-2 COAX) and User and Maintenance monitoring communications (RS-232). Ethernet switches in the C1000 series controller provide a convenient connection point for the Dual Mode CLC model. For multiple C1000's (or inclusion of separate C200's), the RS-485 MultiPac inverter sync connection can be extended through C1000 series controller terminals TB1-44 through TB1-47 or TB1-48 through TB1-51. Figure 63 provides an example of the digital communications connections for a Dual Mode CLC controlling two C1000S/C800S/C600S microturbines.

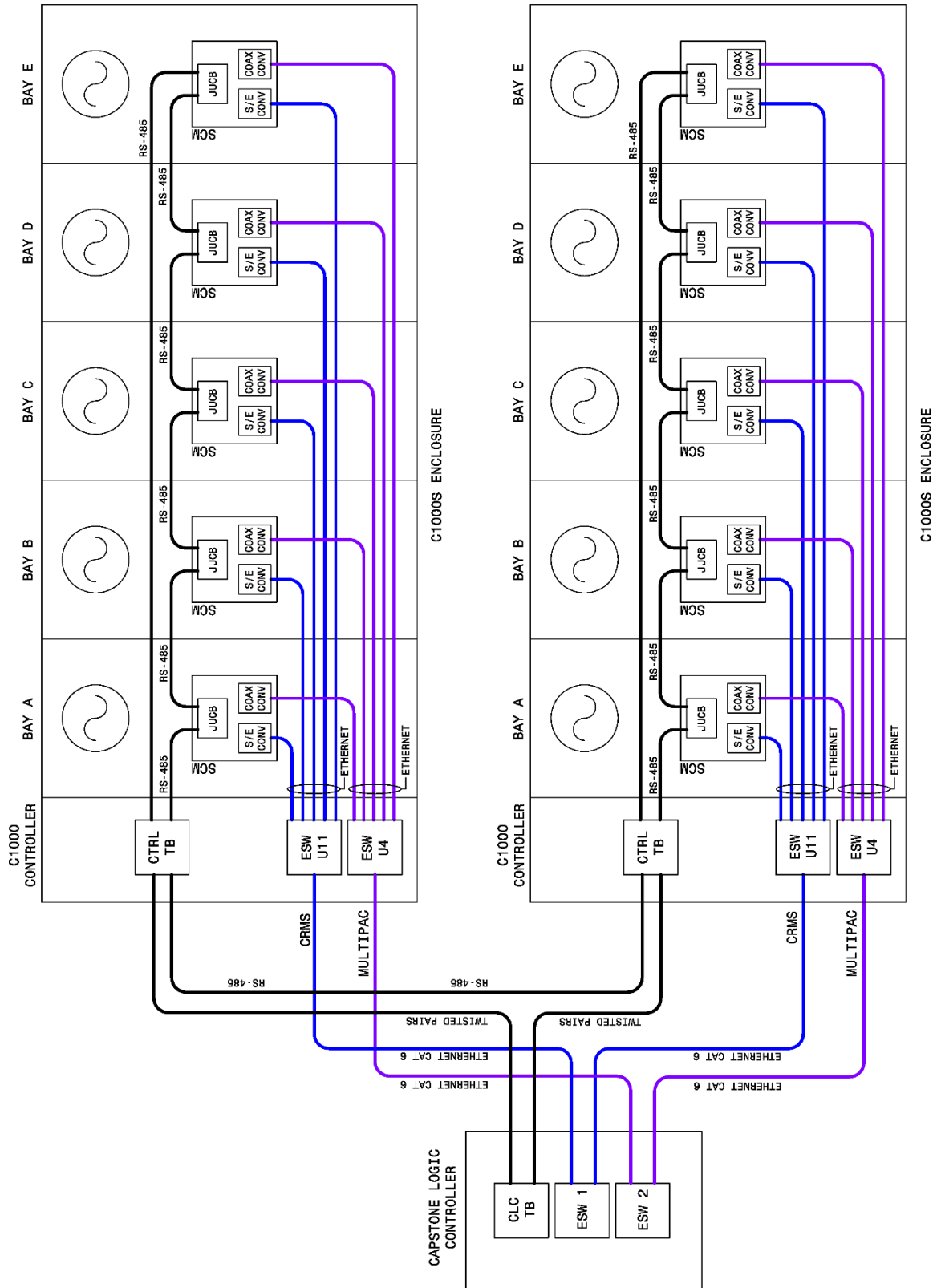


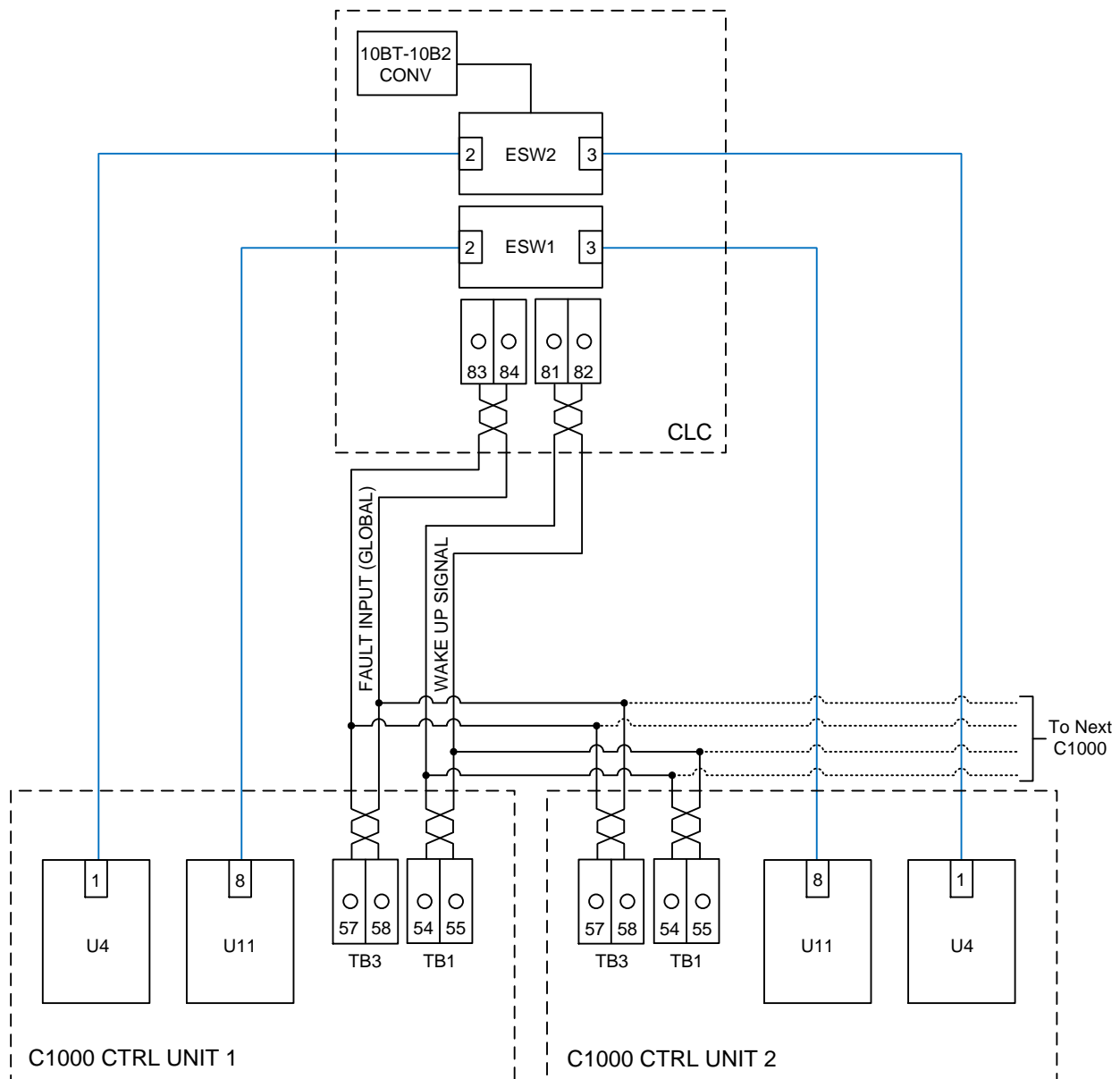
Figure 63. Digital Communications Connections for Dual Mode CLC and Two C1000s



In addition to digital communications lines, hard-wired control connections also include:

- A battery wake-up signal from the CLC to each C1000 controller at terminals TB1-54 and TB1-55.
- A fault input from the CLC to each C1000 controller at terminals TB3-57 and TB3-58.
- An optional global E-Stop signal from an E-Stop switch to the C1000 controller terminals TB1-12 and TB1-13.

Figure 64 shows the digital communications and hard-wired connections from a Dual Mode CLC to Dual Mode C1000's.



**Figure 64. Example Connections from a Dual Mode CLC to a C1000**

#### 8.4.2. Grid Connect C1000 Connections to a CLC

There are two versions of the CLC; one for Dual Mode applications and one limited to grid connect only applications. A grid connect C1000 can be connected to either a Dual Mode CLC or a grid connect only CLC, however the wiring will be slightly different. Grid connect C1000s do not include the star communications topology for the MultiPac master 10Base-2 (COAX) connections. Instead, the C1000 Controller's panel PC is wired to a 10Base-T to 10Base-2 media converter, and COAX lines are then daisy-chained to the C200 microturbine bays. Therefore:

- To connect to a Dual Mode CLC, disconnect the CAT5 Ethernet cable from the 10Base-2 to 10Base-T media converter in the C1000 Controller enclosure and connect an Ethernet cable from the CLC Ethernet switch 2 to the media converter. Turn off the C1000 Controller panel PC. Connect a second Ethernet cable from CLC Ethernet switch 1 to U5 in the C1000 Controller enclosure.
- To connect to a grid connect CLC model, there will be no MultiPac master connection available (no Ethernet switch 2). Therefore, disconnect the CAT5 Ethernet cable from the 10Base-2 to 10Base-T media converter in the C1000 Controller enclosure and turn off the C1000 Controller panel PC. Connect an Ethernet cable from CLC Ethernet switch 1 to U5 in the C1000 Controller enclosure.