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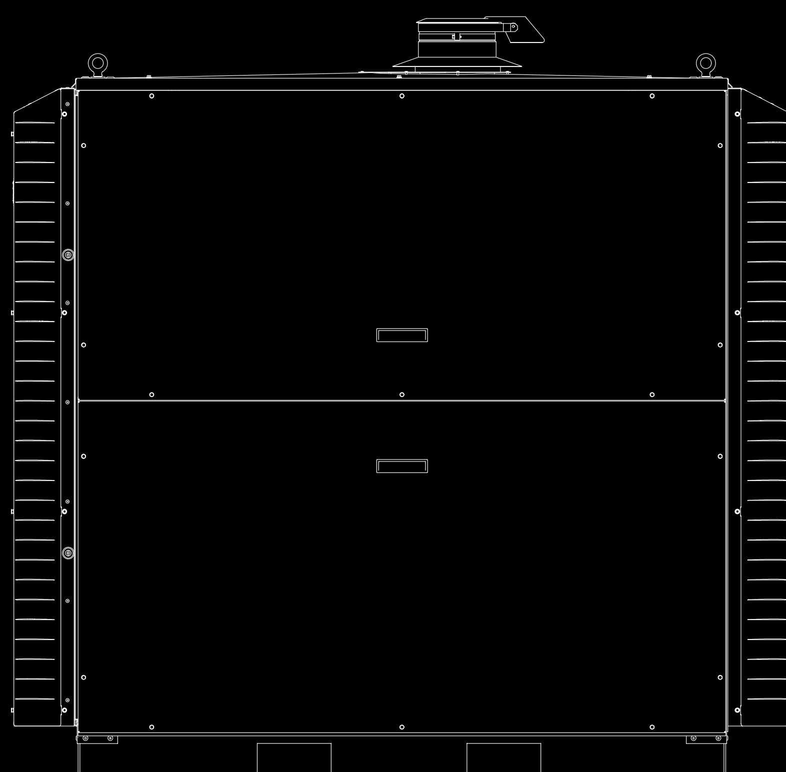
INSTALLATION AND START-UP MANUAL

Model GTAA, GTAB
Microturbine Generator Set



Printed in U.S.A.

950-0600 09-02

WARNING:

The engine exhaust from this product contains chemicals known to the State of California to cause cancer, birth defects or other reproductive harm.

Table of Contents

Safety Precautions

Only trained and experienced personnel authorized by Cummins Power Generation are permitted to open the Microturbine generator set cabinets for start-up, maintenance, service or replacement of parts.

SAVE THESE INSTRUCTIONS and thoroughly read them before operating the Microturbine. Safe operation and top performance can only be attained when equipment is operated and maintained properly.

The following symbols in this manual alert you to potential hazards to operator, service personnel and equipment.

DANGER ***alerts you to an immediate hazard which will result in severe personal injury or death.***

WARNING ***alerts you to a hazard or unsafe practice which can result in severe personal injury or death.***

CAUTION ***alerts you to a hazard or unsafe practice which can result in personal injury or equipment damage.***

GENERAL PRECAUTIONS

Electricity, fuel, exhaust, moving parts and batteries present hazards which can result in severe personal injury or death.

- Keep multi-class ABC fire extinguishers handy. Class A fires involve ordinary combustible materials such as wood or cloth; Class B fires, combustible and flammable liquid and gaseous fuels; Class C fires, live electrical equipment. (ref NFPA No. 10)
- Make sure all fasteners are secure and torqued properly.
- Keep the Microturbine and surrounding area clean, free of obstructions and well ventilated.
- To prevent fire or obstructing cooling air, do not stow flammable materials, equipment or tools inside the Microturbine.
- Do not work on the Microturbine when mentally or physically fatigued or after consuming alcohol or drugs.
- Wear hearing protection.
- Avoid contact with hot exhaust plenums and shields.
- Carefully follow all applicable local, state and federal codes for installation and operation.

MICROTURBINE VOLTAGE IS DEADLY!

- The Microturbine encloses multiple sources of power and residual capacitor voltages. Always verify with a voltmeter that all circuits are de-energized before connecting, disconnecting, or servicing the Microturbine.
- Use caution when working on live electrical equipment. Remove jewelry, make sure clothing and shoes are dry and stand on a dry wooden platform.
- Make sure all electrical connections are tight, clean, dry, and protected from weather and physical stresses.
- Microturbine output connections must be made by a trained and experienced electrician in accordance with applicable codes.

TURBINE EXHAUST IS DEADLY!

- Turbine exhaust includes carbon monoxide (CO), an odorless, colorless, deadly gas. Learn the symptoms of carbon monoxide poisoning. Get out into fresh air immediately if you experience dizziness, throbbing temples, headache, nausea, vomiting, weakness, sleepiness or the like. Get medical attention if the symptoms persist.
- When the Microturbine is installed indoors, vent the turbine exhaust to the outside in accordance with applicable codes.
- Exhaust piping must be gas tight. It must not terminate in enclosed or sheltered areas or near building doors, windows or vents.
- Provide ample fresh air for combustion and ventilation.

FUEL IS FLAMMABLE AND EXPLOSIVE

- Do not smoke or turn electrical switches ON or OFF where fuel fumes are present or in areas sharing ventilation with fuel tanks or equipment. Keep flame, sparks, pilot lights, arc-producing equipment and all other sources of ignition well away.
- The fuel supply system must be designed, constructed, installed and inspected in accordance with applicable codes. Fuel lines must be secure, free of leaks and separated or shielded from electrical wiring.
- A manual fuel shutoff valve must be provided within sight of the Microturbine.
- If you smell gas, immediately shut down the Microturbine, close the fuel shutoff valve, and locate and repair the leak.
- Take care to prevent leaks and the accumulation of gas. Leaks can lead to explosive accumulations of gas. Natural gas rises when released and can accumulate under hoods and inside housings and buildings. LPG sinks when released and can accumulate inside housings and basements and other below-grade spaces.

SERVICE PRECAUTIONS

The Microturbine encloses multiple sources of power and residual capacitor voltages. Before connecting, disconnecting, or servicing the Microturbine, ***always***:

- Command the Microturbine to OFF.
- Open and lock the dedicated disconnect switch to isolate the Microturbine from the utility grid or loads.
- If the Microturbine is equipped with batteries, open the battery isolation switch and unplug the battery cable.
- Wait five (5) minutes for residual capacitor voltage to decay.
- Verify with a voltmeter that no voltage is present on any electrical terminals.

Introduction

ABOUT THIS MANUAL

This manual presents information necessary for the installation, commissioning and start-up of the generator set (Microturbine) models listed on the front cover. Information necessary for operation is found in the *Operation Manual*.

This manual DOES NOT provide application information for selecting a generator set or designing the installation.

SAFETY

The Microturbine has been carefully designed to provide safe and efficient service when properly installed, maintained, and operated. However, the overall safety and reliability of the complete system is dependent on many factors outside the control of the generator set manufacturer. To avoid possible safety hazards, make all mechanical and electrical connections to the Microturbine exactly as specified in this manual. All systems external to the Microturbine (fuel, exhaust, electrical, etc.) must comply with all applicable codes. Make certain all required inspections and tests have been completed and all code requirements have been satisfied before certifying the installation is complete and ready for service.

CERTIFICATIONS, PERMITTING AND CODES

National and International Standards

Your Microturbine system is designed and manufactured in accordance with a variety of national and international standards.

Since the Microturbine produces electricity up to 480 volts (defined by the NEC as low voltage, having 600V or less), and since it is a gas-powered device, installation frequently requires one or more permits from local regulatory agencies.

It is not practical to list here the requirements of each authority having jurisdiction and how the Microturbine meets those requirements. Cummins Power Generation recognizes that for each installation, such a comparison must eventually be made and offers the following information in an effort to ease this process.

Refer to *Appendix A: Outline Drawings* for weights, dimensions, required clearances, and other items.

If you cannot locate the information you require, please call your Cummins Power Generation Distributor.

NFPA - National Fire Protection Association

Microturbine systems meet applicable NFPA requirements. There are additional NFPA requirements which must be met regarding your installation of the Microturbine.

NEC - United States National Electric Code (NFPA 70/1996)

Microturbine systems as manufactured meet all applicable NEC requirements. Your Microturbine installation must meet all applicable NFPA 70 requirements.

NEMA - National Electrical Manufacturers Association

Microturbine systems conform to NEMA 250-1997 pertaining to the system enclosure weather-resistance rating.

IEEE - Institute of Electrical and Electronic Engineers

At rated output, Microturbine systems comply fully with IEEE 519.

Site Preparation

PHYSICAL PLACEMENT

When selecting a location for the Microturbine, you should consider the following main factors:

1. Mounting and placement
2. Public access and safety
3. Service access clearances
4. Fuel gas piping
5. Electrical and control wiring
6. Intake and cooling air supply
7. Exhaust heat
8. Sound considerations

The Microturbine is designed for either indoor or outdoor operation. It should be placed on a firm level surface with less than a 2% grade. The surface should be sufficient to bear the weight and should have sufficient drainage to prevent standing water.

Mounting and/or securing the system to the surface is recommended. Microturbines produce virtually no vibration. If ground settling or earthquakes are possibilities, then provisions should be made to relieve stresses at both electrical and fuel gas connections, and at any intake air or exhaust ducting.

More specific requirements for items such as concrete pads, concrete or steel impact protection posts, seismic mountings, seismic fuel valves, and other items may apply in some regulatory jurisdictions. Consult local codes to ensure compliance with all regulations.

PUBLIC PROTECTION AND SAFETY

Clearances around the Microturbine and access to the system must be maintained in accordance with local regulations. During operation, the upper external surfaces of the Microturbine become very hot and could cause injury.

Although the system is lockable, it is not vandal resistant. If used in areas of casual contact, consider preventing access to the Microturbine by the general public with a fence or similar lockable barrier.

LIFTING AND TRANSPORT

The Microturbine enclosure features a base with pockets for forklift or pallet jack forks. Refer to *Appendix A: Outline Drawings* for lifting locations and be sure to use a forklift or other lifting means of sufficient capacity when positioning the Microturbine. Some installation locations may require crane lifting. Note that lifting points are on the top of the Microturbine. If lifting by crane, spreader bars and rigging will be required.

⚠WARNING ***The Microturbine has a high center of gravity and may tip when lifting. Take precautions to adequately secure the unit prior to lifting.***

RECOMMENDED SERVICE CLEARANCES

Local electrical codes shall prescribe minimal rear clearances necessary for access to the electrical junction box (which is typically three feet). The enclosure features access panels that are easily removed and replaced to service system components. Refer to *Appendix A: Outline Drawings* for service clearances.

Fuel Connections

NFPA 37 and local codes should be used as a guide for installing the Microturbine fuel supply. See *Appendix C: Specifications* regarding the fueling rated rate (energy consumption) required.

The gas flow required for Microturbine operation is determined by the energy consumption rate, generally measured in therms per hour. The consumption rate is affected by the electrical load, the energy content of the gas, the gas temperature, and the gas pressure. The local gas supplier can calculate the required flow rate and pipe sizing from the energy consumption rates (*Appendix C: Specifications*).

The following fuel related items must be installed prior to initial commissioning:

1. Piping from the gas supply to the Microturbine.
2. Manual fuel isolation valve for the Microturbine.
3. Main fuel gas filter.
4. Purge valve to flush out the gas supply line.
5. Pressure regulator. If a pressure regulator is required, it must be rated for the maximum fuel gas flow for the local gas line pressure and the minimum operating inlet pressure.

Items 2, 3, 4 and 5 are available from Cummins Power Generation as a kit (Figure 1), with or without Item 5. Pipe connections are 1/2 inch NPT.

Adequate fuel supply without pressure loss at high flow rates is crucial for proper operation. The peak fuel consumption rate occurs during full load from a cold start (approximately two minutes in duration) and can be up to 1-1/2 times the normal steady state full power fuel rate.

The gas supply interface point is located at the rear of the enclosure. Refer to the Refer to *Appendix A: Outline Drawings*. The inlet fitting is (JIC) AN-12 37° male flare.

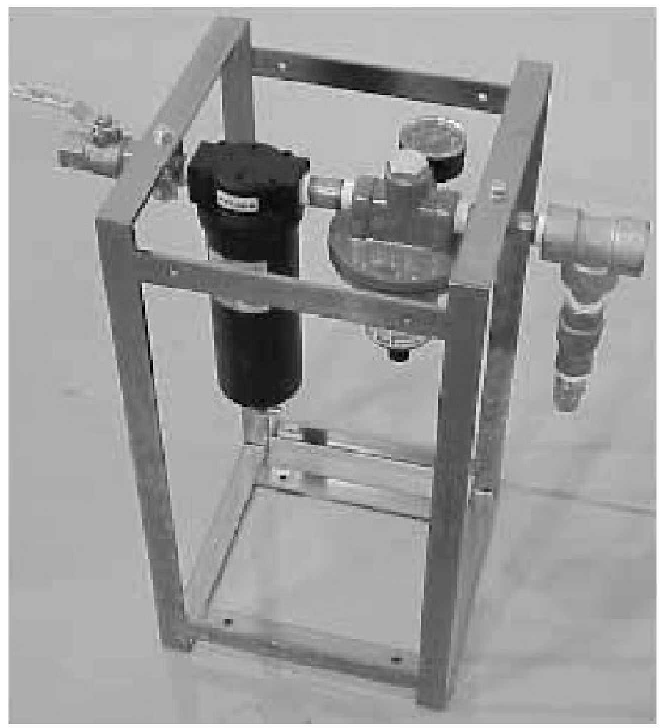


FIGURE 1. FUEL ACCESSORY KIT

Air for Combustion and Cooling

Air is used for cooling and combustion within the Microturbine and for cooling the electronics components and gas compressor (if so equipped). Inlet air should be taken from a common source and should be as cool as possible to maximize available power output and efficiency. See *Appendix C: Specifications* regarding air flow rates.

Filters are included in the enclosed Microturbine packages for both the engine air and the electronics cooling air.

CAUTION ***Air and/or exhaust flow restrictions which exceed specifications can degrade performance and cause damage to internal components.***

Exhaust Connections

The Microturbine is powered by a gas turbine that produces a hot exhaust gas stream. See *Appendix C: Specifications* regarding exhaust gas temperatures. The Microturbine includes an exhaust stack, but care must be taken in the installation plans to keep people and flammable materials away from the exhaust pipe and the exhaust stream. For exhaust duct design purposes, use the maximum exhaust temperature as the upper limit for the operating temperature range.

The Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines, NFPA 37, requires that owners/users provide a minimum spacing of eight inches from combustible surfaces. The owner/user may add additional exhaust piping but must maintain the eight inches lateral clearance.

⚠WARNING ***The exhaust gas is hot. Personnel warnings should be posted and thermal shields should be provided to prevent direct contact with the exhaust extensions.***

If required, exhaust piping and chimneys should be designed, constructed and installed in accordance with NFPA 37. Careful consideration should be made during the design and construction processes to ensure that the backpressure limit (8 inches WC) is not exceeded. If the exhaust piping includes a flue duct system, an isolation or back-flow prevention device should be installed.

If the installation includes an exhaust heat recovery system or exhaust duct work, the length and size of exhaust pipe and/or duct must meet local as well as industrial codes (for example, NFPA regulations).

⚠CAUTION ***Back pressure will reduce the power output and excessive or fluctuating back pressure could damage the internal components of the Microturbine and/or void the warranty!***

Electrical Connections—Grid

ELECTRICAL CABLES AND SWITCHGEAR

The owner/operator must supply the electrical cable and switchgear through which the Microturbine delivers its output power. These must be capable of safely handling the maximum potential loads, and must meet all applicable local regulations.

⚠WARNING ***Consult NFPA 70 and applicable local codes and standards before wiring the Microturbine. A trained and experienced electrician is required to do the work.***

The electrical connection terminal block for the Microturbine can be found in the Power Bay area of the UCB located at the rear of the enclosure (Figure 2 or 3).

⚠WARNING ***Where local codes require it, a permanent plaque must be installed at each Microturbine and at each point of utility connection showing all sources of power.***

For Grid Connect operation, the Microturbine should be connected as closely as possible to the service entrance to minimize supply impedances.

TIP: Connection of the Microturbine at points other than the utility service entrance may introduce impedances that cause local voltage rises beyond the Microturbine's acceptable limits during operation.

BREAKERS / FUSED DISCONNECTS

A UL listed circuit breaker or fused disconnect with visible air gap must be installed between the Microturbine and the user's electrical subpanel, at a distance no greater than 25 feet from the Microturbine. The type of disconnect and faultcurrent ratings of the device must meet all applicable local codes.

Breakers or disconnects should always have lockout provisions to facilitate maintenance safety.

⚠WARNING ***When installing the circuit breaker or fused disconnect, ensure the equipment meets the maximum fault current rating specified by the local utility. All equipment must be properly grounded.***

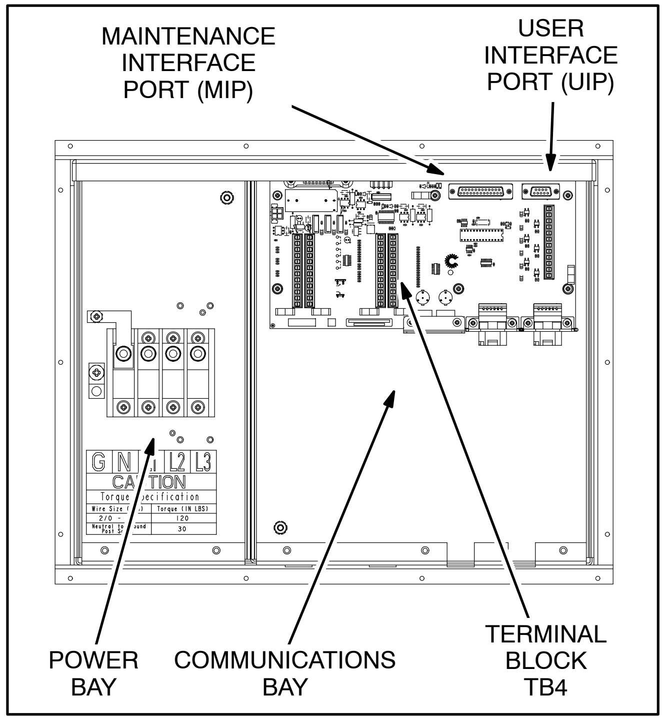


FIGURE 2. GTAA USER CONNECTION BAY (UCB)

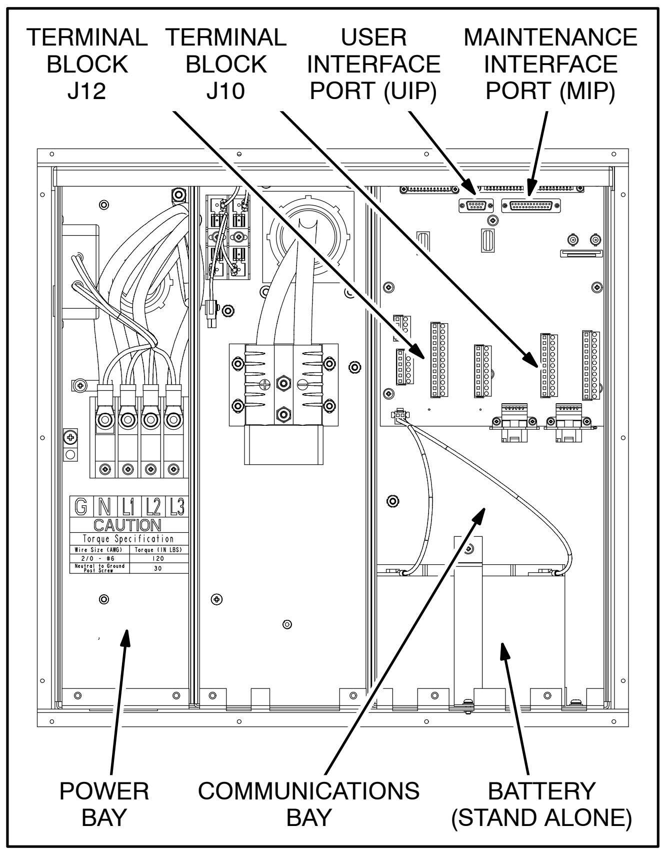


FIGURE 3. GTAB USER CONNECTION BAY (UCB)

CONNECTION CIRCUITS

The Microturbine, during Grid Connect operation, is designed primarily for ground-referenced, balanced phase-to-neutral operation.

An **EARTH GROUND** of the Microturbine case is MANDATORY. Refer to Figures 5 and 6 for proper grounding location.

WARNING ***Electrical wiring, including protection and grounding, should conform to NFPA 70 and all local electrical codes.***

WARNING ***Neglecting to properly ground the Microturbine system can cause damage to the Microturbine system.***

PHASE ROTATION

During Grid Connect operation, the Microturbine phase terminals may be connected to the grid in any order.

CIRCUIT CURRENT CAPACITY AND WIRING

The selected output voltage of the Microturbine and applicable regulations will determine circuit current capacity requirements. See *Appendix C: Specifications* regarding the rated continuous current in each phase at full-load and unity power factor. In the Grid Connect mode, output current will be in phase with grid voltage, with approximately unity power factor.

The United States National Electric Code (NEC) requires a branch circuit to be rated not less than 125% of rated load (NEC 220-3).

Typically, under NEC provisions, 600 VAC copper conductor is used for the High Voltage Terminal Block connection in the Power Bay.

Per UL 2200, the tightening torque on the terminal block must be as shown in the following table:

WIRE SIZE (AWG)	TORQUE (lb-in)	
	Straight Slot	Hex Head
2/0 - #3	50	120
#4 - #6	45	120

GROUNDING

WARNING ***The Microturbine case must always be connected to earth ground during operation.***

GRID CONNECT INTERLOCK

The Grid Connect Interlock consists of a pair of 5 volt dry circuit terminals (Figure 4). They are found on the printed circuit board in the Communications bay—Figure 2 (**Model GTAA**) or Figure 3 (**Model GTAB**). A closed circuit between these terminals permits Grid Connect operation, an open circuit disallows Grid Connect operation.

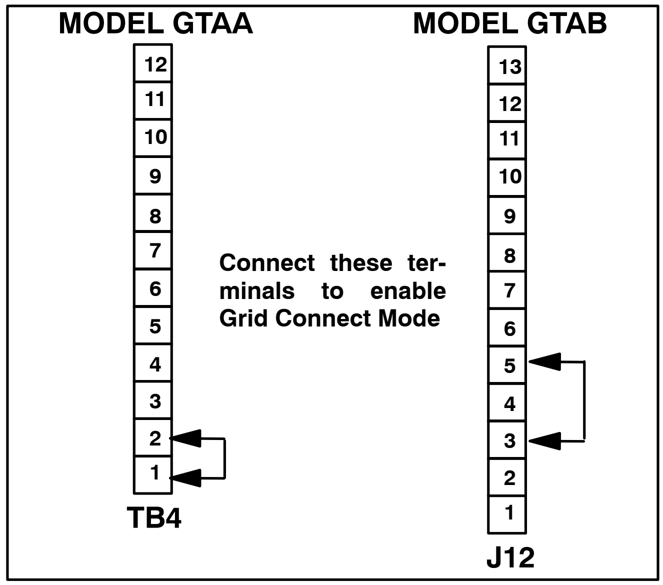


FIGURE 4. GRID CONNECT MODE

Note: The Microturbine will not operate as shipped. The Microturbine is shipped with BOTH sets of interlock terminals open.

OVERVOLTAGE SHUT-DOWN

A common Grid Connect installation problem is high impedance in the connection circuit. The current generated by the Microturbine acts on this impedance to raise the voltage at the terminals of the system. If impedance is excessive, the voltage may exceed the overvoltage trip point and the system will fault and shut down due to overvoltage as the output power (current) increases. A lower impedance transformer, an autotransformer, or adjusting transformer taps may correct this problem.

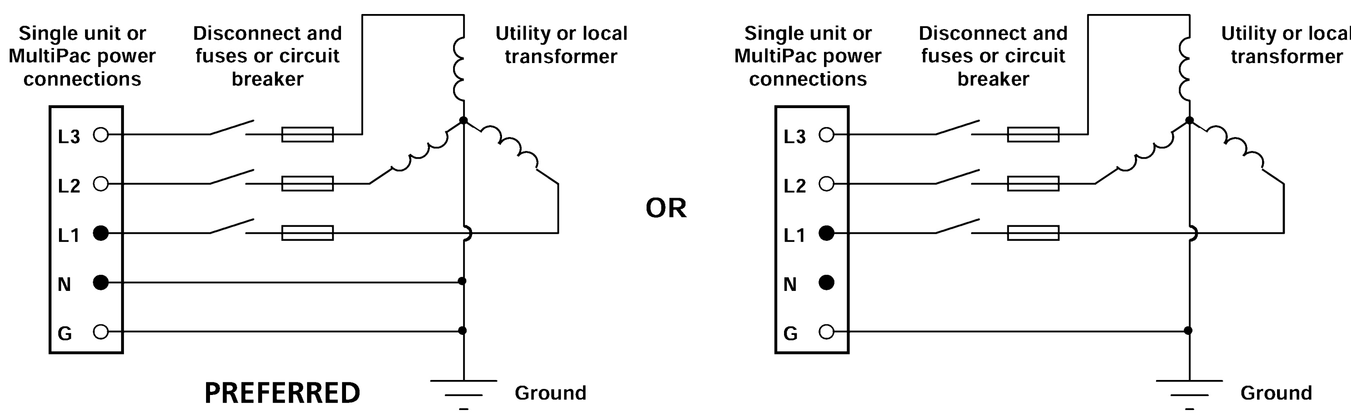
PERMITTED UTILITY CONNECTIONS

A voltage transformer for the Microturbine will be required for any of the following grid connect applications (45 kVA minimum for **Model GTAA** or 75 kVA minimum for **Model GTAB**):

1. Circuit connect voltages other than 400-480 VAC.
2. Connection circuits with wiring schemes other than the two allowed configurations:
   - 4-wire Wye with ground (preferred)
   - 3-wire Wye with ground
3. Connection to a system where the impedance is high enough to cause over-voltage at the noted output current of the system. In this case a tapped or auto intervening transformer is required to lower the nominal voltage, if this cannot be done with the installed transformers.

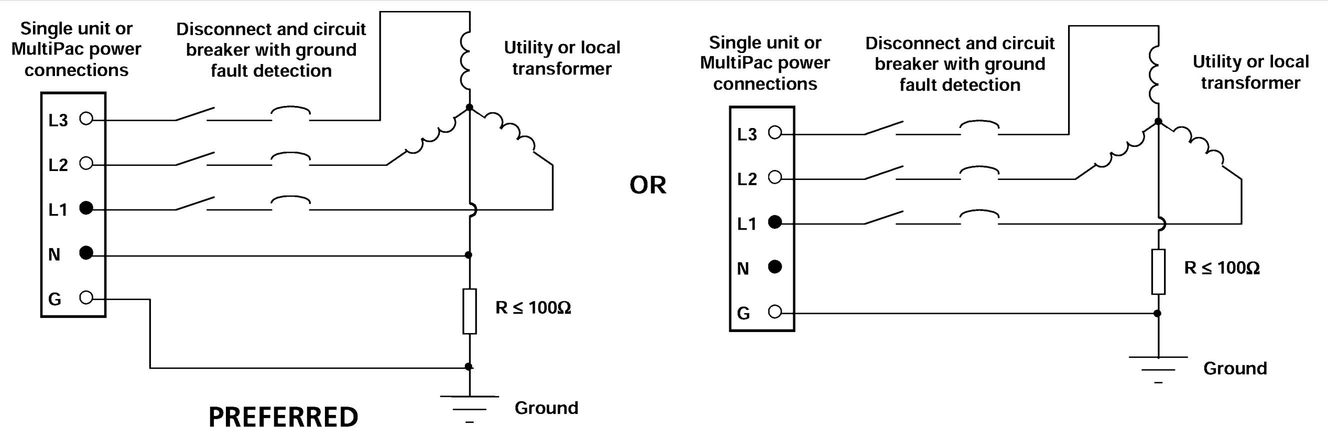
Refer to Figures 5 and 6 for permitted utility or transformer connections.

WARNING ***Connecting the Microturbine to a phase-grounded utility or transformer is NOT PERMITTED.***



The neutral-to-ground bar must be removed from all single or MultiPac grid connected MicroTurbines

FIGURE 5. PERMITTED CONNECTIONS TO SOLID-GROUNDED WYE UTILITY OR TRANSFORMER



The neutral-to-ground bar must be removed from all single or MultiPac grid connected MicroTurbines

Any branch circuit protection used for individual systems in a MultiPac must use circuit breakers with ground fault detection that is coordinated with the ground fault current level.

FIGURE 6. PERMITTED CONNECTIONS TO RESISTANCE-GROUNDED WYE UTILITY OR TRANSFORMER

Electrical Connections—Stand Alone

OVERVIEW

If the Microturbine is equipped with the Stand Alone option, the operator must supply the electrical cable and switchgear through which the Microturbine delivers its output power. These must be capable of safely handling the maximum potential loads, and must meet all applicable local regulations.

WARNING ***Consult NFPA 70 and applicable local codes and standards before wiring the Microturbine. A trained and experienced electrician is required to do the work.***

Electrical wiring should conform to NFPA 70, NEC, and local electrical codes.

The electrical connection terminal block for the Microturbine can be found in the Power Bay area of the UCB located at the rear of the enclosure (Figure 7 or 8).

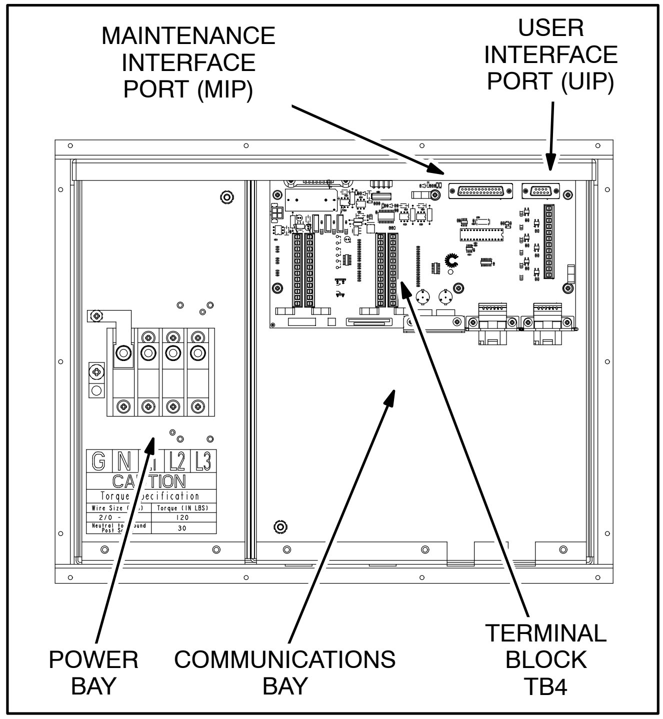


FIGURE 7. GTAA USER CONNECTION BAY (UCB)

VOLTAGE

Microturbine output voltage may be established from 150 to 480 volts AC, phase to phase.

PHASE ROTATION

The phase rotation is *clockwise*: L1-L2-L3.

CAUTION ***Improper phase connections can damage connected loads. Cummins Power Generation cannot be held responsible for equipment damage caused by improper connections. It is the operator's responsibility to verify the proper phase connections between the Microturbine and the load(s).***

LOAD CIRCUITS

Microturbine output is three phases and neutral. These may be used in any combination, limited on **Model GTAA** to 46 A_{rms} / 10 kW on each phase or on **Model GTAB** to 100 A_{rms} / 20 kW on each phase. The nominal Stand Alone voltage setting is available between any two phases. The voltage available between any phase and neutral is the nominal divided by 1.732 (square root of 3). Single phase and/or unbalanced loads can be accommodated respecting the current and power limits above. **The Microturbine Neutral must always be grounded.**

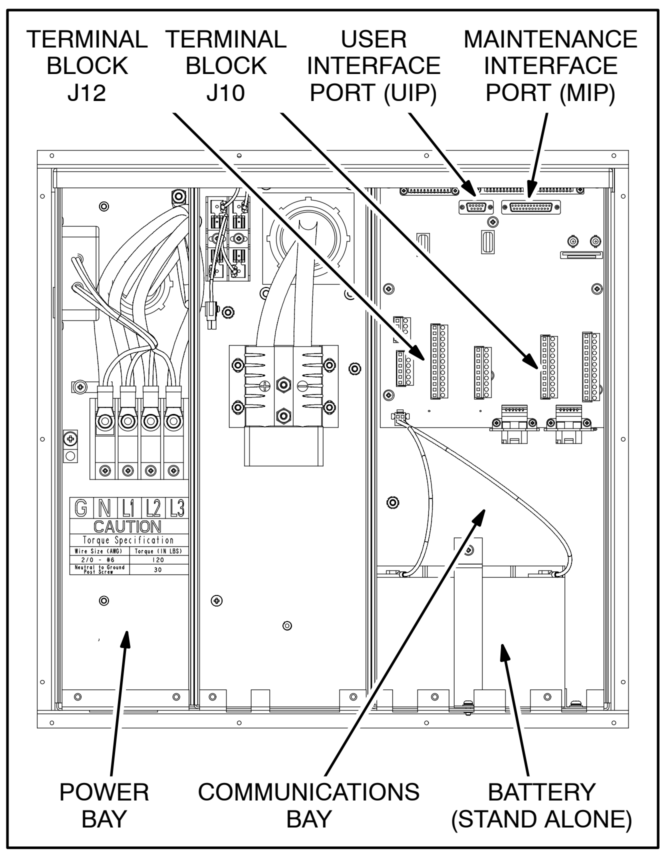


FIGURE 8. GTAB USER CONNECTION BAY (UCB)

LOAD CAPACITY

Microturbine output is current limited. The Microturbine can operate loads with any power factor, so long as current limits are not exceeded.

The current consumed by the load(s) (I) is a function of real power (Watts), volts (V) and the power factor (pf):

$$I = W / (1.73 \times V \times pf)$$

For **Model GTAA**, transient current must not exceed 54 A_{rms} (root mean square current) or 46 A_{rms} continuous. For **Model GTAB** transient current must not exceed 110 A_{rms} transient or 100 A_{rms} continuous. The allowable power factor in any given installation will be a function of the operating voltage and real load power demand. For example, with a total 60 kW load operating at 480 VAC, the lowest allowable power factor is:

$$60{,}000 / (480 \times 100 \times 1.73) = 0.72$$

Operating at 400 VAC, the lowest allowable power factor is:

$$60{,}000 / (400 \times 100 \times 1.73) = 0.86$$

Operating at 346 VAC, the lowest allowable power factor is:

$$60{,}000 / (346 \times 100 \times 1.73) = 1.0$$

Operating voltages lower than 346 will consequently reduce the total available output power of the Microturbine according to:

$$W = 100 \times 1.73 \times V \times pf$$

⚠WARNING ***Incorrect determination of load capacity can cause the Microturbine to fault and result in damage to the battery.***

Motor Loads

Many loads, especially electric motors, require very high starting current, as much as ten times their steady-state requirements. The Microturbine can deliver an absolute maximum of 155 A_{pk} (Peak Amps) for approximately 10 seconds. ($A_{pk} = A_{rms} \times 1.41$, which is equivalent to 110 A_{rms} for a linear load.)

Large loads may cause the AC output voltage to droop. If the system is unable to achieve nominal voltage after a programmable timeout period, it will shut down without damage. Under most conditions **Model GTAA** will line start motors up to approximately 10 hp (horsepower) and **Model GTAB** will line start motors up to approximately 20 hp.

In many cases, the Microturbine can start larger motors (**Model GTAA** up to 40 hp and **Model GTAB** up to 80 hp) using the RampStart feature or an installed soft start device.

RampStart: The Microturbine may be programmed to increase voltage and/or frequency from an adjustable starting point, at an adjustable rate, up to nominal. RampStart occurs whenever the output contactor closes; during normal power enable or Auto-Enable. See the section on RampStart Settings in *Appendix B: Configuring the Microturbine*. The start voltage and the frequency ramp rate must be set correctly to prevent motor saturation.

The Ramp Starting ramp voltage/frequency ratio should not exceed the rated-voltage/rated-frequency ratio. Also, the voltage ramp is typically longer than the frequency ramp, and the typical ramp times are between 1 and 10 seconds.

⚠WARNING ***Incorrect settings of the Ramp features can cause damage to connected loads.***

CIRCUIT CURRENT CAPACITY AND WIRING

The selected output voltage of the Microturbine and applicable regulations will determine circuit current capacity requirements. See *Appendix C: Specifications* regarding the rated continuous current in each phase at full-load and unity power factor.

The United States National Electric Code (NEC) requires a branch circuit to be rated not less than 125% of rated load (NEC 220-3).

Model GTAA output current is limited to less than 54 A_{rms} and **Model GTAB** to less than 110 A_{rms} even under load short circuit conditions. This level of fault current is often insufficient to trip standard thermal or magnetic circuit breakers.

To isolate faults in load branch circuits, the use of ground fault interrupting circuit breakers is recommended.

Typically, under NEC provisions, 600 VAC copper conductor is used for the High Voltage Terminal Block connection in the Power Bay.

Per UL 2200, the tightening torque on the terminal block must be:

WIRE SIZE (AWG)	TORQUE (lb-in)	
	Straight Slot	Hex Head
2/0 - #3	50	120
#4 - #6	45	120

STAND ALONE INTERLOCK

For Stand Alone operation, the Stand Alone interlock terminals in the Communications Bay must be shorted (Figure 9). They are found on the printed circuit board in the Communications bay—Figure 7 (**Model GTAA**) and Figure 8 (**Model GTAB**).

Note: The Microturbine will not operate as shipped. The Microturbine is shipped with BOTH sets of interlock terminals open.

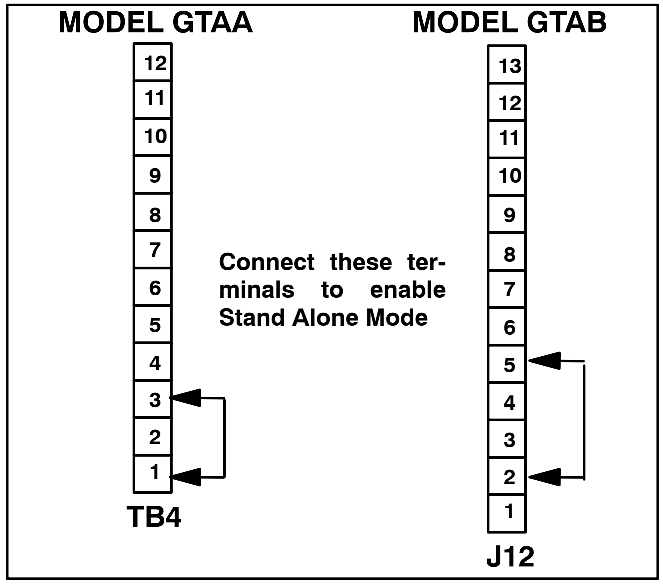


FIGURE 9. STAND ALONE CONNECTIONS

TRANSFORMERS

The electrical output of the Microturbine in Stand Alone mode may be used in any wiring scheme or combination of schemes which respects the current and power limits on each phase and neutral. This flexibility will often preclude the need for a transformer between the Microturbine and connected loads Transformers will be needed in Stand Alone mode when loads of differing voltage requirements are to be connected or when full power is needed for loads with voltages less than 346V.

⚠WARNING ***Connecting the Microturbine to a phase-grounded utility or transformer is NOT PERMITTED.***

GROUNDING

WARNING ***The Microturbine system case must always be connected to earth ground during operation.***

The Ground terminal of the Microturbine output terminal block must **ALWAYS** be connected to earth ground during operation.

The Neutral terminal of the Microturbine output terminal block **MUST BE** connected to ground, either at the Microturbine or at the load, but **NOT** BOTH! This is the purpose of the Neutral to Ground Post (Figure 10).

If the Microturbine system is connected to a Stand Alone circuit or loads with floating (ungrounded) neutral, the Microturbine Neutral to Ground Post should remain installed as shipped.

If the Microturbine system (including the neutral wire) is connected directly to a load or a transformer with its neutral connected to ground, the Microturbine Neutral to Ground Post should be removed.

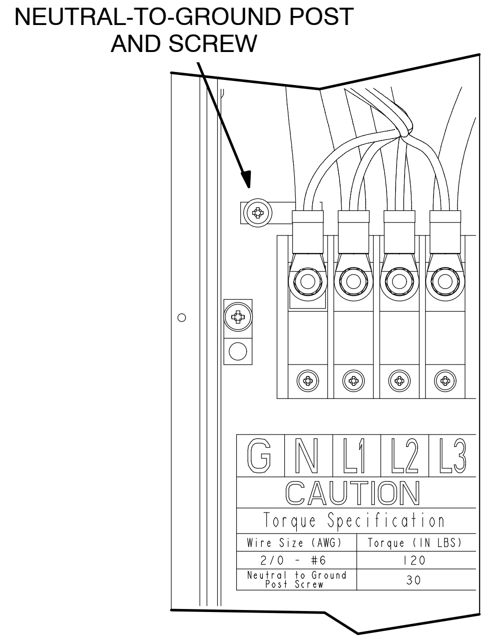
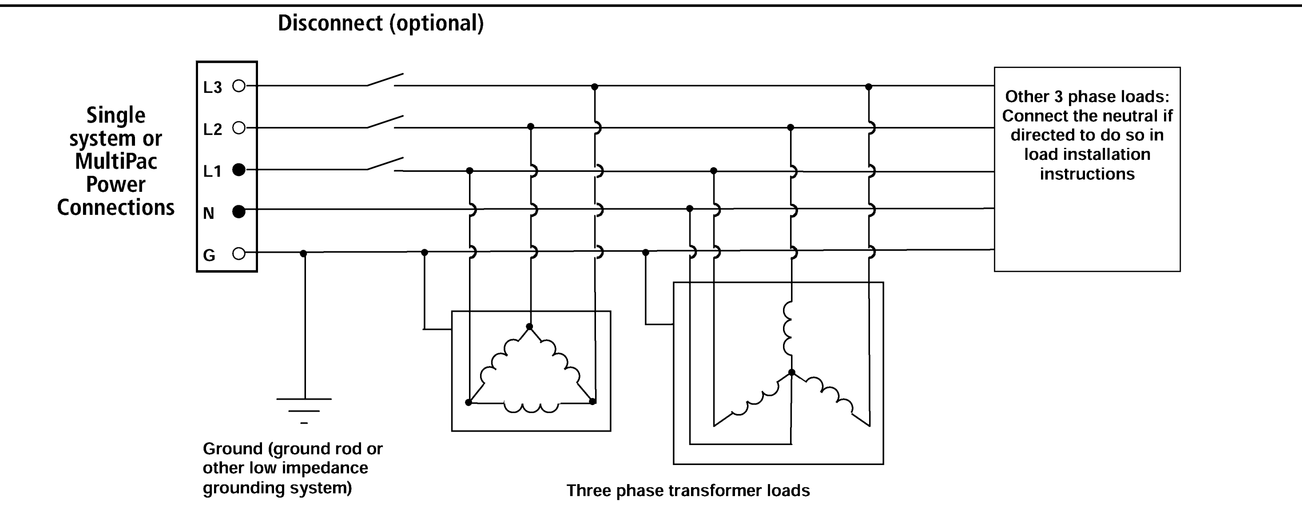


FIGURE 10. NEUTRAL-TO-GROUND

PERMITTED STAND ALONE CONNECTIONS

Refer to Figures 11 and 12 for permitted Stand Alone wiring connections.

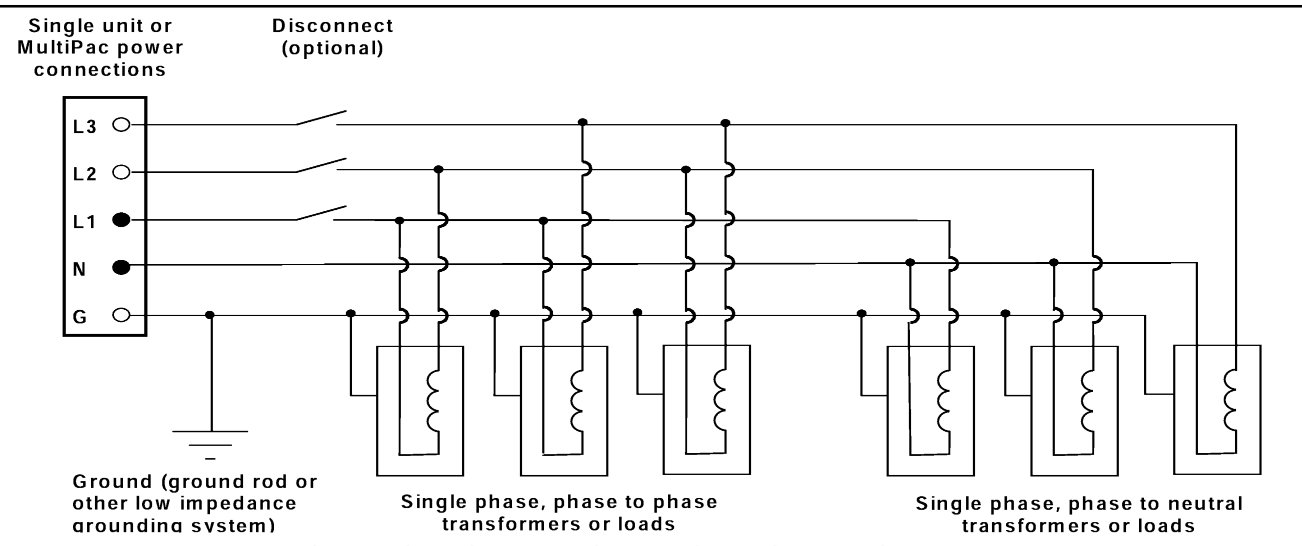
Note: In MultiPac Stand Alone systems the neutral must be connected to ground in one location only.



The neutral must be connected to ground in one location only.

The total single-phase unbalanced load must not exceed 10 kW for each **Model GTAA** or 20 kW for each **Model GTAB**

FIGURE 11. STAND ALONE CONNECTIONS FOR THREE-PHASE LOADS



The neutral must be connected to ground in one location only.

The total single-phase unbalanced load must not exceed 10 kW for each **Model GTAA** or 20 kW for each **Model GTAB**

FIGURE 12. STAND ALONE CONNECTIONS FOR SINGLE-PHASE LOADS

Electrical Connections—Dual Mode

DUAL MODE ELECTRICAL CONNECTIONS

If your Microturbine is equipped with the Stand Alone option, it is capable of either Grid Connect operation or Stand Alone operation and may be converted from one to the other simply and easily. An installation designed to switch between Grid Connect and Stand Alone operation is called a Dual Mode Installation. Loads on the same circuit with the Microturbine and which may be powered either by the grid or the Microturbine in Stand Alone mode are termed **Protected** loads.

Conversion from one mode to the other requires a shutdown of the Microturbine, and then:

1. Transfer of the electrical connections
2. Reconfiguration of the interlocks and software
3. Restart of the Microturbine

These steps may be accomplished manually, or automatically. Automatic transfer and reconfiguration may be accomplished with the Automatic Dual Mode Controller (sold separately).

Whether manual or automatic, the electrical conversion from one mode to the other must be planned with care, particularly the neutral and ground connections. Safety, code, and functional requirements must all be met.

INTERLOCKS

Interlock terminal pairs assure that the Microturbine does not attempt to start or operate in an unintended or unsafe mode. The appropriate interlock must be closed, and the other interlock must be open in order to enable either operating mode (Figure 13).

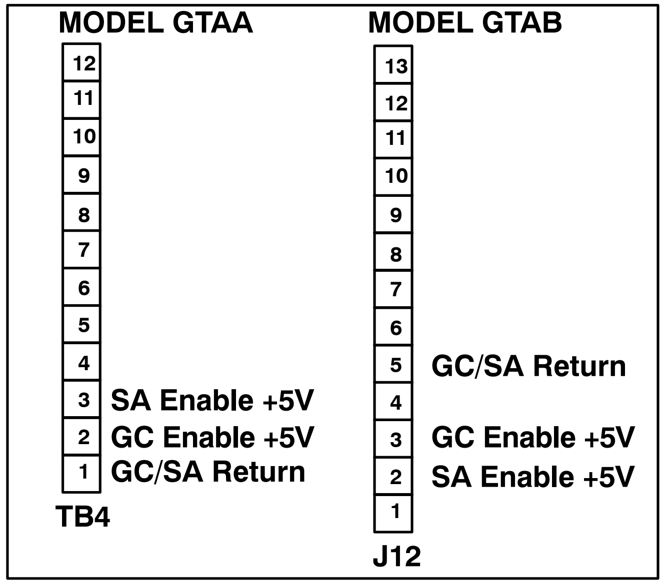


FIGURE 13. DUAL MODE CONNECTIONS

SIZING PROTECTED LOADS

Note: Protected loads in a Dual Mode application must be sized as though the Microturbine will operate the loads in Stand Alone mode.

The aggregate load is current limited as described in the Stand Alone section. Total power on **Model GTAA** should not exceed approximately 25 kW or on **Model GTAB** approximately 50 kW to allow for Microturbine power deration during high ambient temperature conditions. **Model GTAA** motor loads should be limited to 10 hp line start or 40 hp dedicated using RampStart or an external soft start device. **Model GTAB** motor loads should be limited to 20 hp line start or 80 hp dedicated.

Note: Larger motor or inductive loads may be accommodated via the use of “soft starters” or adjustable speed drives. The **Model GTAA** limit of 54 A_{rms} for 10 seconds must not be exceeded nor the **Model GTAB** limit of 110 A_{rms} for 10 seconds.

PHASE ROTATION

Dual mode applications must be certain to match the phase rotation of the Microturbine in Stand Alone with the phase rotation of the grid to prevent load phase reversal when switching modes.

GROUNDING AND NEUTRAL

The neutral to ground connection requirements in the Dual Mode operation are identical to those in the Grid Connect mode. The neutral-to-ground bar (Figure 10) MUST be removed from all Microturbines.

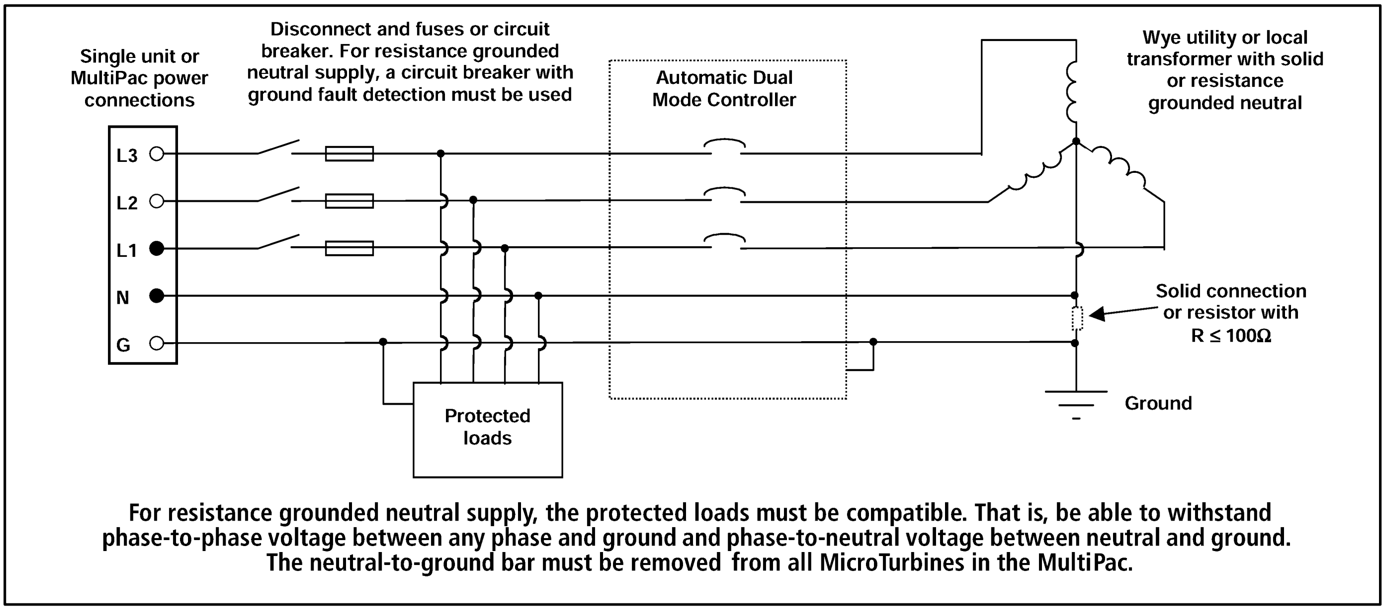


FIGURE 14. DUAL MODE CONNECTIONS FOR DIRECT CONNECTION OPERATION

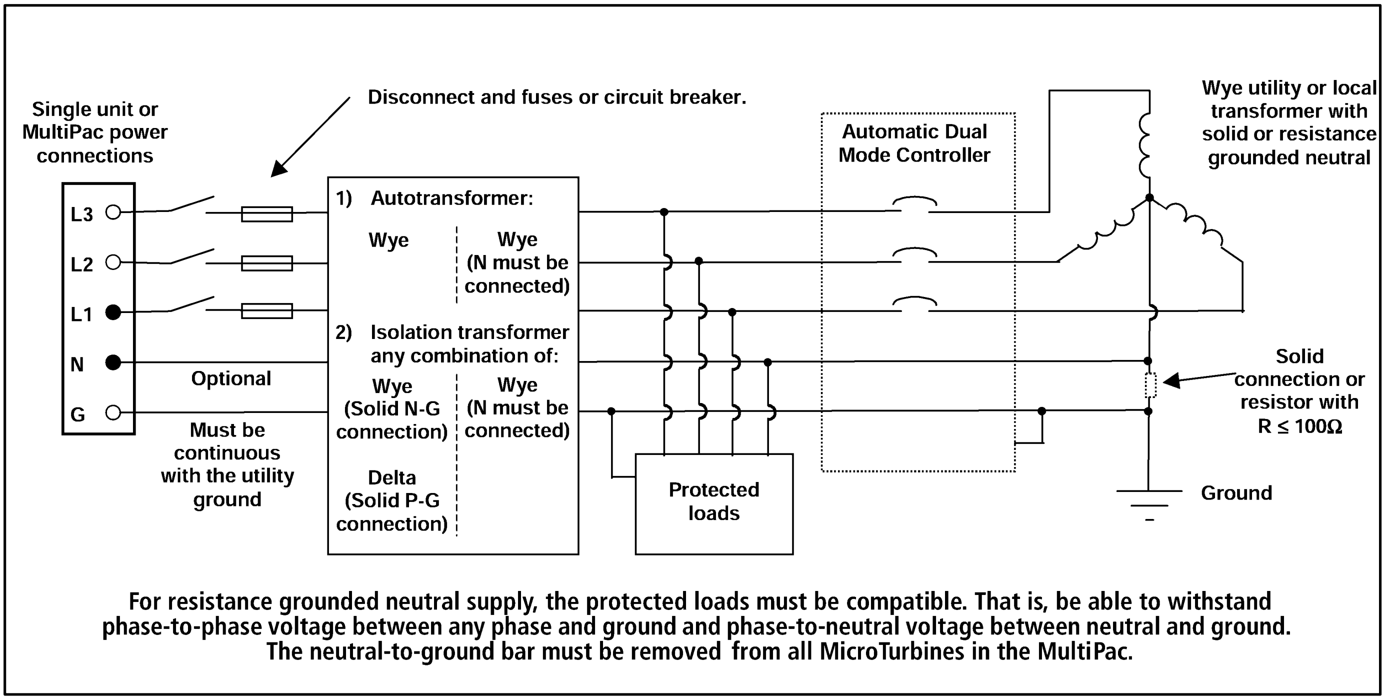


FIGURE 15. DUAL MODE CONNECTIONS FOR INDIRECT CONNECTION OPERATIONS

Electrical Connections—MultiPac

Individual systems may be grouped and connected together as a MultiPac to behave as a single larger power generator. The instructions regarding power connections, signal connections, and Stand Alone motor load limitations must be strictly observed.

MultiPac Power Connections

Power connections between the MultiPac systems will be needed, and these connections must consider the proper phase wiring, neutral wiring, and grounding connections between the various systems. Refer to following diagrams for permitted MultiPac wiring connections.

All wiring, including protection and grounding, must be in strict accordance with standard electrical safety practices and with all local code specifications.

Connections for the MultiPac are supported in the Stand Alone and the Grid-Connect modes.

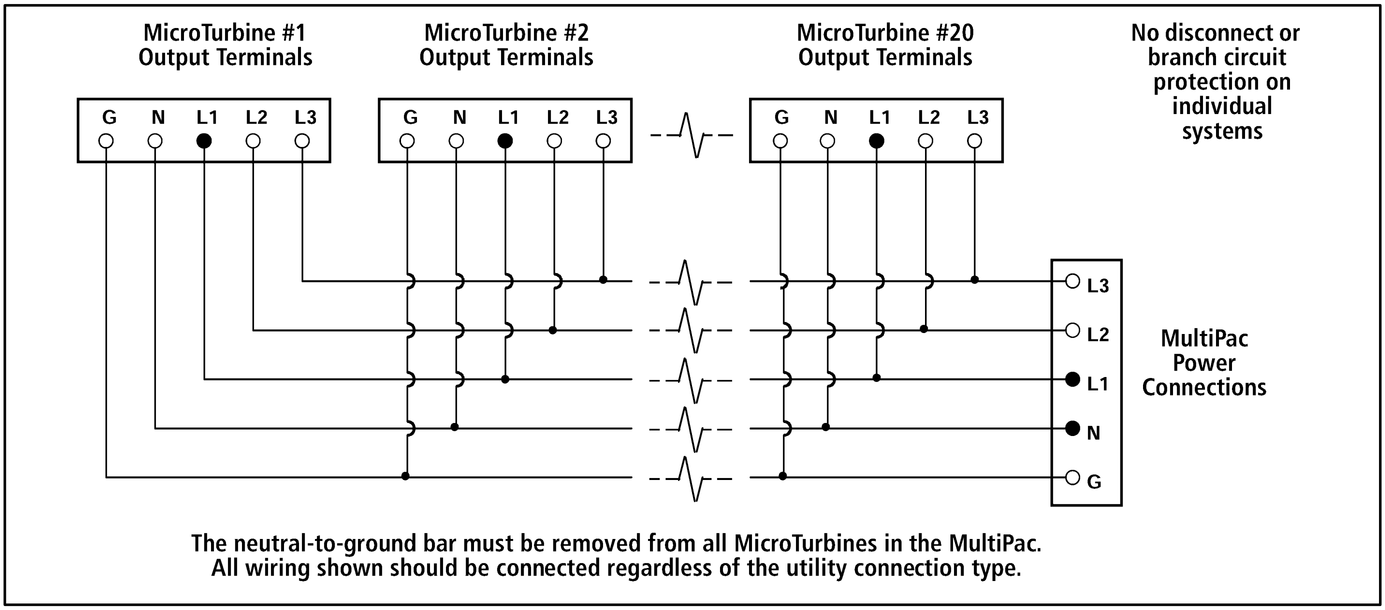


FIGURE 16. POWER CONNECTION BETWEEN SYSTEMS FOR GRID-CONNECTED / DUAL MODE—BASIC

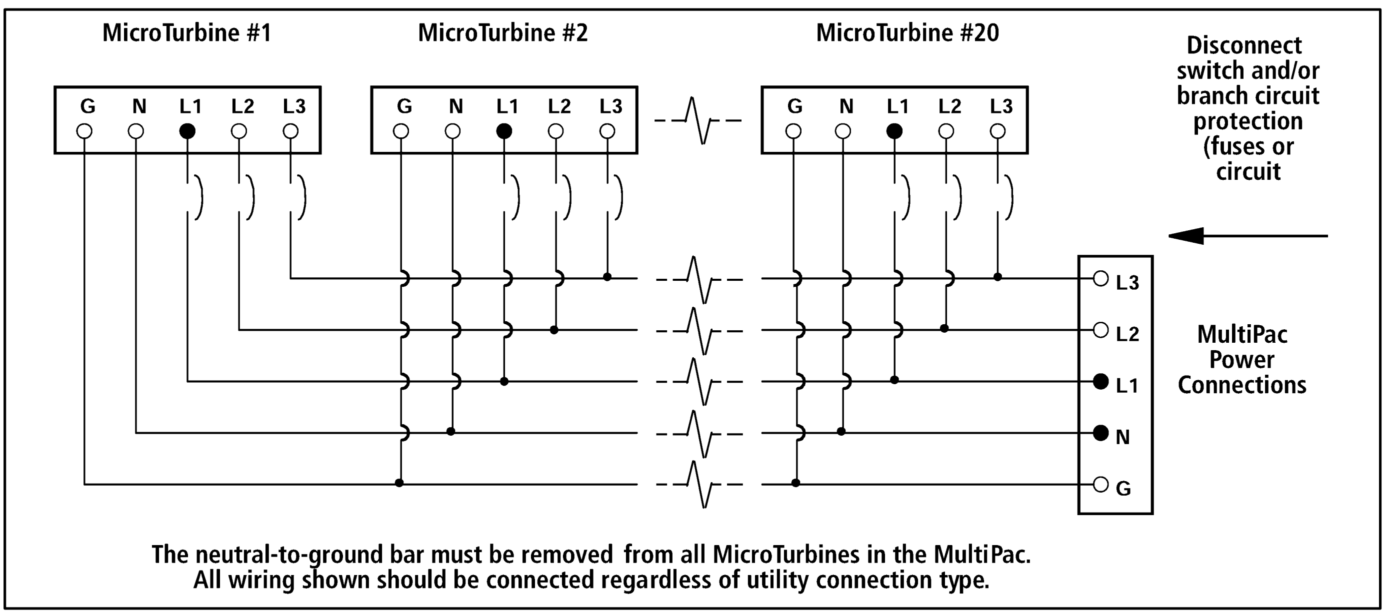


FIGURE 17. POWER CONNECTION BETWEEN SYSTEMS FOR GRID-CONNECTED / DUAL MODE—OPTION

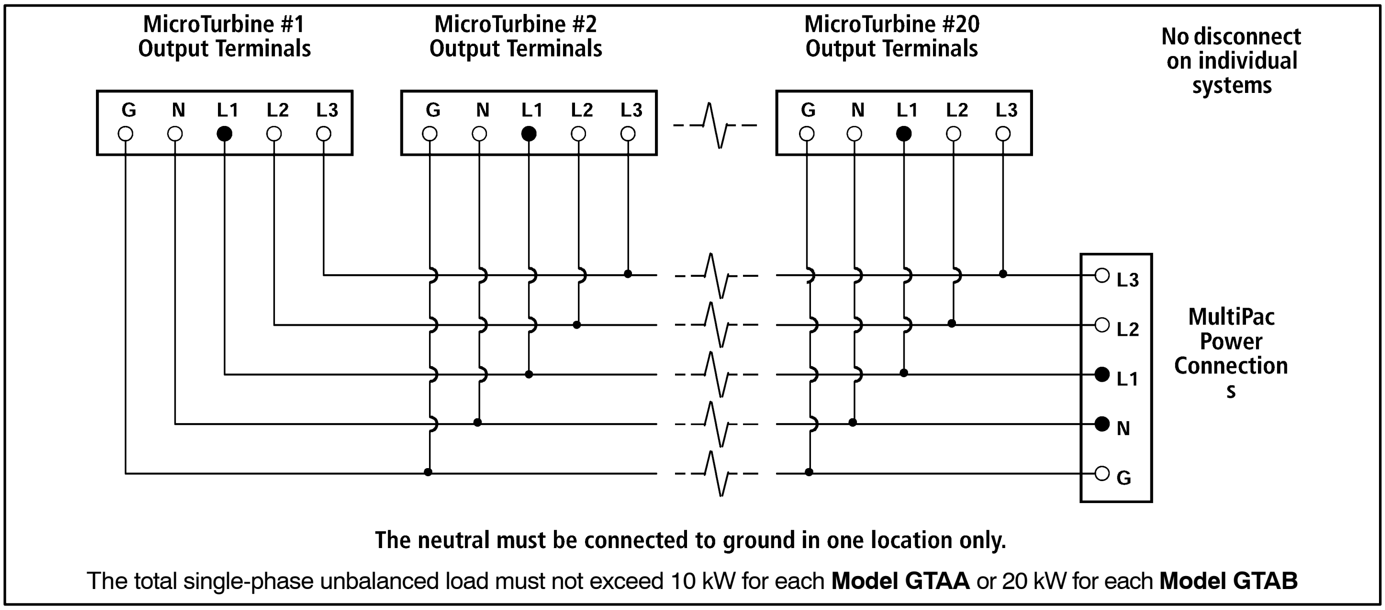


FIGURE 18. POWER CONNECTION BETWEEN SYSTEMS FOR STAND ALONE MODE—BASIC

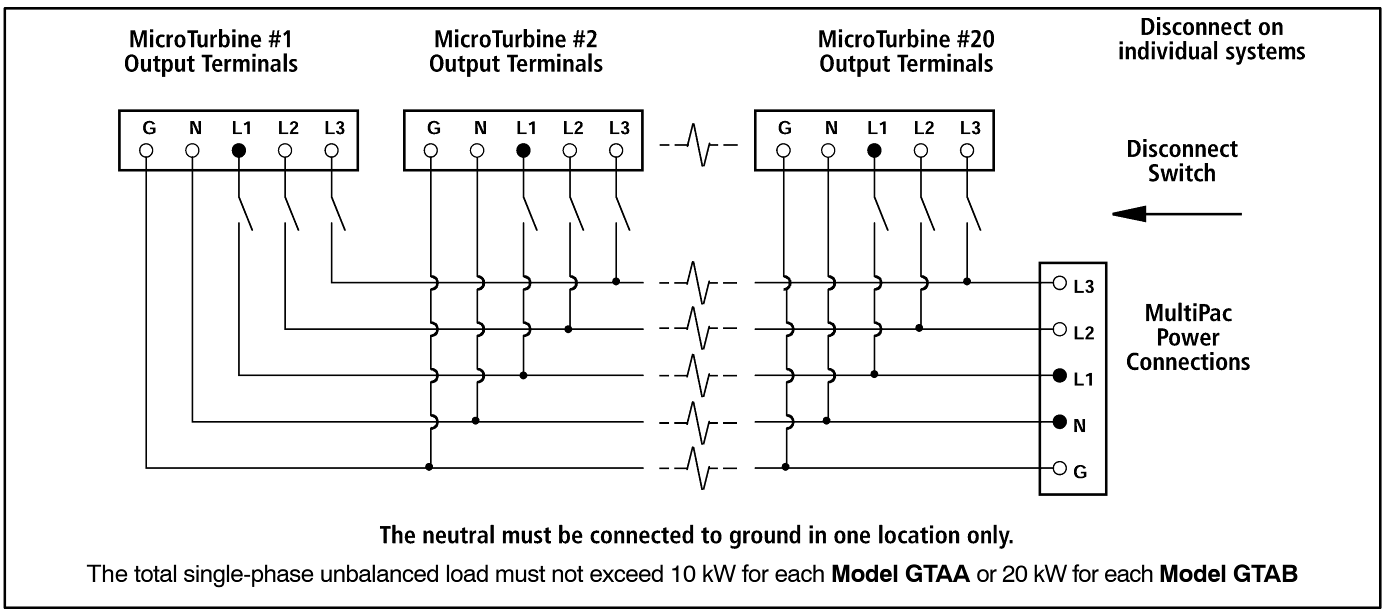


FIGURE 19. POWER CONNECTION BETWEEN SYSTEMS FOR STAND ALONE MODE—OPTION

MultiPac Communications Connections

Communications connections are also provided and consist essentially of Inter-Communications Harness connections. Communications connections include the following typical connections:

Local Emergency Stop - In this arrangement, a jumper or ESTOP switch is required for each system in the MultiPac setup. The Emergency Stop Switch will only stop the local system to which it is attached.

Global Emergency Stop - In this arrangement, a jumper or ESTOP switch is required on only one system within the MultiPac setup. The Emergency Stop Switch will stop all systems within the MultiPac setup.

User and Maintenance Ports - The operating master system within the MultiPac can access commands and data for the master system or for any controlled system. An operating controlled system can only access local data and limited commands.

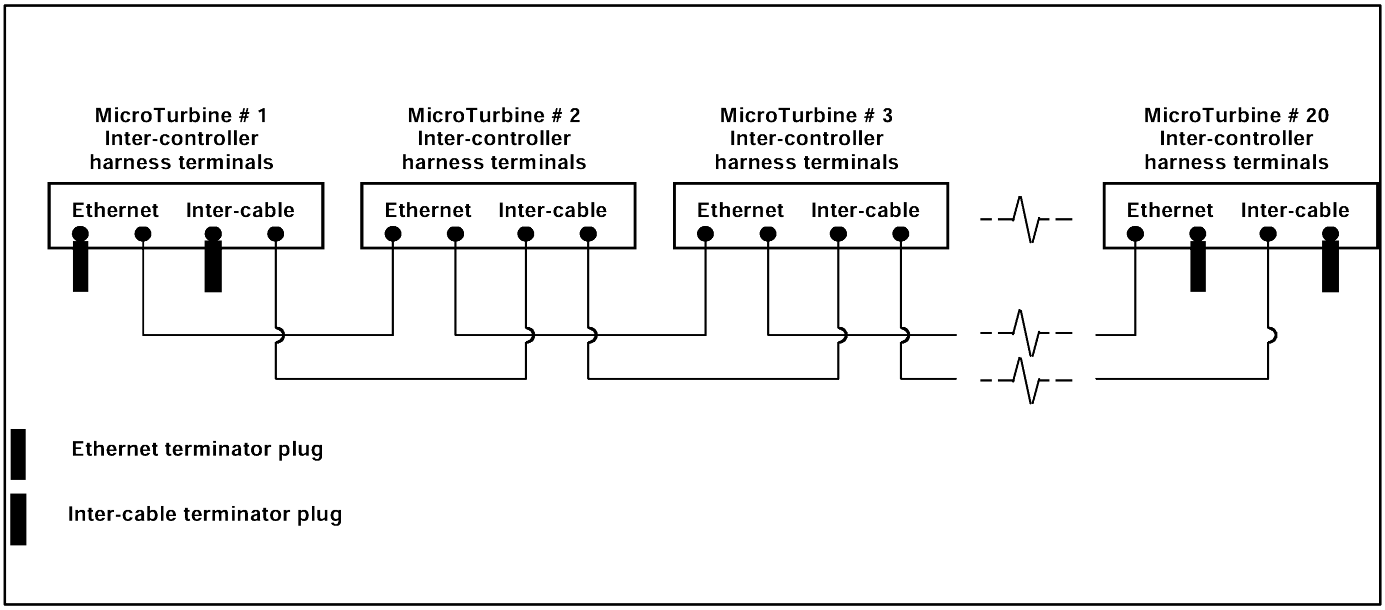


FIGURE 20. SIGNAL CONNECTIONS FOR INTER-COMMUNICATIONS HARNESS

Communications Connections

Set-up, control, and monitoring of the Microturbine is managed through the display panel, the user interface port (UIP), and the maintenance interface port (MIP). Some operating communications are accomplished via the field wiring terminals. Primary user communications include:

- Establishing operating parameters and settings
- Starting and stopping the Microturbine
- Adjusting power output
- Recovering operating data

Maintenance and commissioning communication functions include:

- Establishing operating modes
- Establishing operating parameter set points and limits
- Establishing dispatch modes and parameters
- Recovering event data, and troubleshooting

These communications are accomplished through the use of one of the following items:

Display Panel

The front-mounted display panel includes a keypad, a display window, navigation buttons, and system controls.

User Interface Port (UIP)

A Dsub9 RS-232 serial communications port is located in the user connection bay and is available for remote operation using RS-232 standard protocol. A Microsoft Windows 95 / 98 / 2000 / NT based computer, RS-232 null modem cable (length up to 25 feet), and Remote Monitoring System software (sold separately) are used to communicate through this port. Optionally, a modem and an analog phone line may be connected to the port for remote operation. See Figure 21 for **Model GTAA** and Figure 22 for **Model GTAB**.

Note: Excessive cable lengths can introduce noise into the line which can diminish the communication ability.

Maintenance Interface Port (MIP)

A Dsub25 RS-232 serial communications port is located in the user connection bay and is functionally identical to the UIP. System diagnostics and software upgrades are performed via this port. See Figure 21 for **Model GTAA** and Figure 22 for **Model GTAB**.

Field Wiring Terminals

Electrical terminals are provided for the following connections:

- Optional emergency stop switch
- User power (24 VDC, 0.7 A)
- Modem power (12 VDC, 0.5 A)
- Remote power meter
- Remote start/stop switch
- Battery wake

The terminals are located in the user connection bay. See Figure 21 for **Model GTAA** and Figure 22 for **Model GTAB**.

Output Relays

The Microturbine includes six output relays which may be programmed to represent any of the 11 machine states, and programmed as needed to be *active open* or *active closed* when the system is operating in that state:

- Standby (Default Relay1)
- Run (Default Relay 2)
- Contactor Closed (Default Relay 3)
- Fault (Default Relay 4)
- Stand Alone (Default Relay 5)
- SA Load (Default Relay 6)
- Disable
- Fuel On
- Fuel Purge (Liquid fuel only)
- Load State
- External Load

Note: All relays default to active open.

The output relay connections are accessed through terminal pairs on TB5 (Figure 21 for **Model GTAA**) and J15 (Figure 22 for **Model GTAB**) in the Communications Bay. Also, see menu descriptions for details. These output relays are simple contact closures intended for dry contact circuits, rated to 0.1 Amp, 125 VAC_{rms}.

Fault Inputs

Two fault inputs are available for **Model GTAA** on TB4 (Figure 21) and for **Model GTAB** on J12 (Figure 22) in the Communications Bay. Fault Inputs are not optically isolated. They require a contact closure between the fault input and digital ground.

Controls Connections

Microturbine systems are self-contained and do not normally require external controls, however, some dispatch modes require external control signals.

These control signals are accomplished by closing or opening continuity of a dry contact circuit, rated to 5 volts. These circuit connections are made via pairs of terminals on the terminal blocks in the Communications Bay.

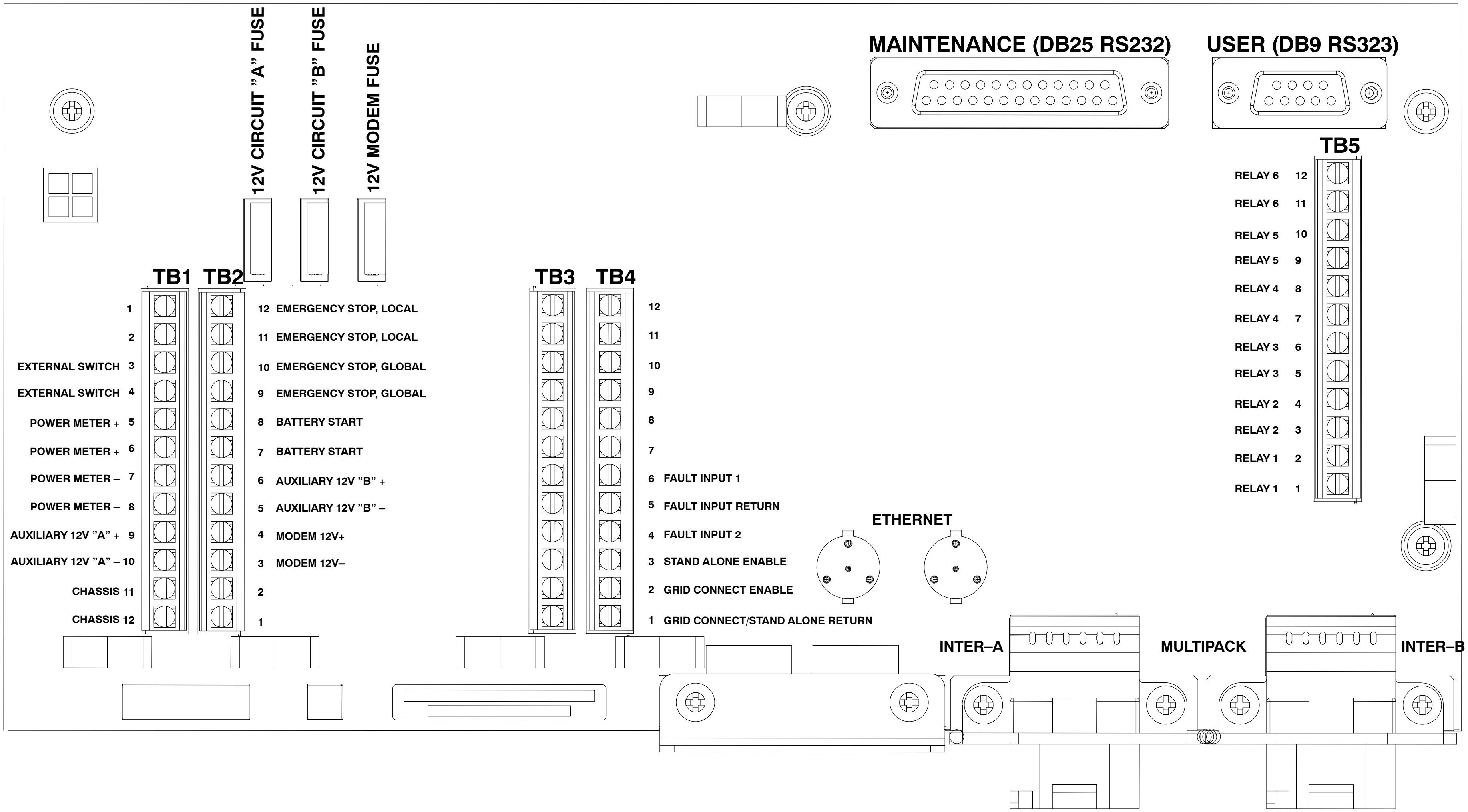


FIGURE 21. MODEL GTAA USER CONNECTIONS

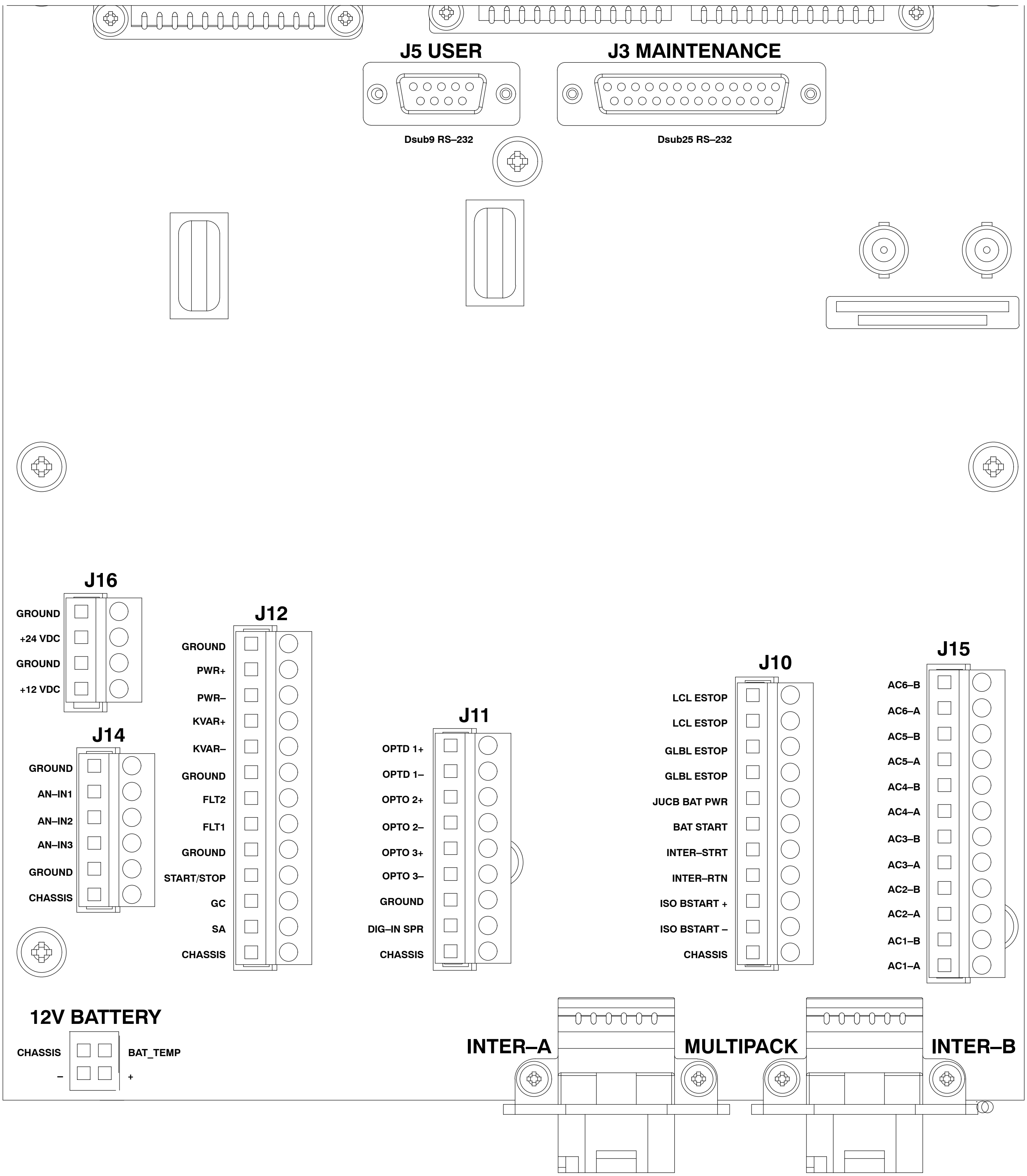


FIGURE 22. MODEL GTAB USER CONNECTIONS

Commissioning

WARNING ***Before attempting to start the Microturbine, read all of this manual and ensure that the commissioning procedure has been completed by a Cummins Power Generation Authorized Service Provider.***

Completion of the commissioning process should precede initial start-up of the Microturbine. The commissioning should be performed by a Cummins Power Generation Authorized Service Provider.

The commissioning process is intended to ensure proper installation and successful operation of the Microturbine. The commissioning process includes an evaluation of the installation including:

- Site inspection
- Mechanical installation
- Fuel system
- Electrical system
- Communications interfaces
- Configuring the Microturbine for operation
- Microturbine operational checkouts

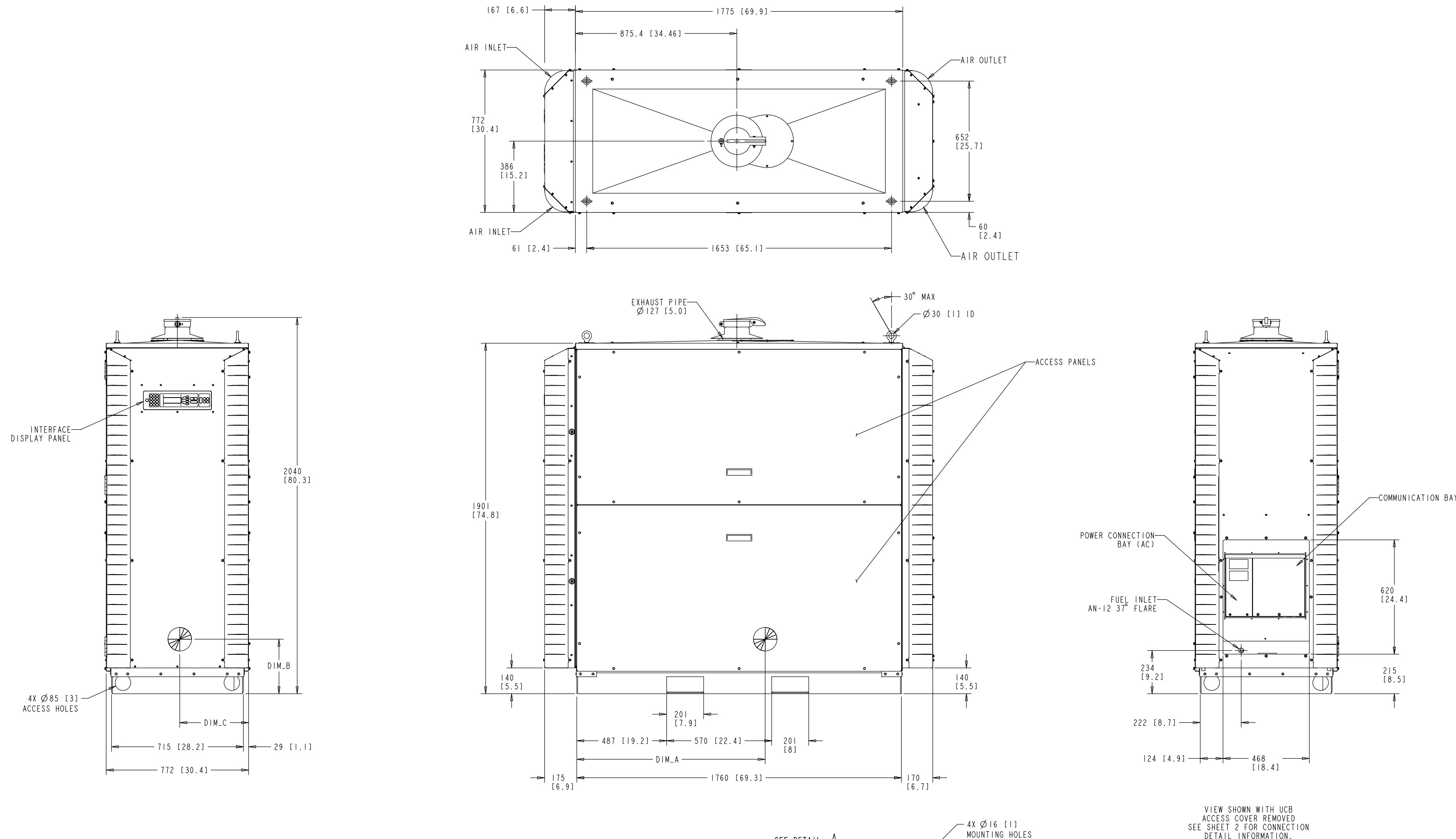
CAUTION ***There are system settings which must be initialized before first start-up for successful operation! See Appendix A.***

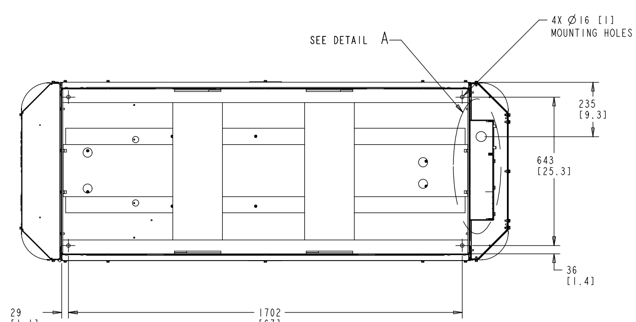
At the completion of the commissioning process, the Microturbine is ready for normal operation, and a completed Commissioning Check List is returned to Cummins Power Generation. **RETURN OF THE CHECKLIST IS REGISTRATION OF THE MICROTURBINE WARRANTY.**

The authorized service provider should establish and record initial operating parameters before starting the Microturbine for the first time in a new installation.

Appendix A: Outline Drawings

Refer to the Outline Drawing (Pages A-2 to A-5) for weights and dimensions, required clearances, noise levels, and other items.





CONFIGURATION	DIM_A	DIM_B	DIM_C	WT KG [LBS]
GTAA-SA LP	865 [34.1]	495 [19.5]	357 [14.1]	575 [1270]
GTAA-GC LP	900 [35.4]	535 [21.1]	357 [14.1]	439.4 [970]
GTAA-SA HP	854 [33.6]	495 [19.5]	350 [13.8]	552.5 [1219.6]
GTAA-GC HP	885 [34.8]	535 [21.1]	350 [13.8]	416.9 [920]

FIGURE 23. MODEL GTAA OUTLINE DRAWING—SHEET 1

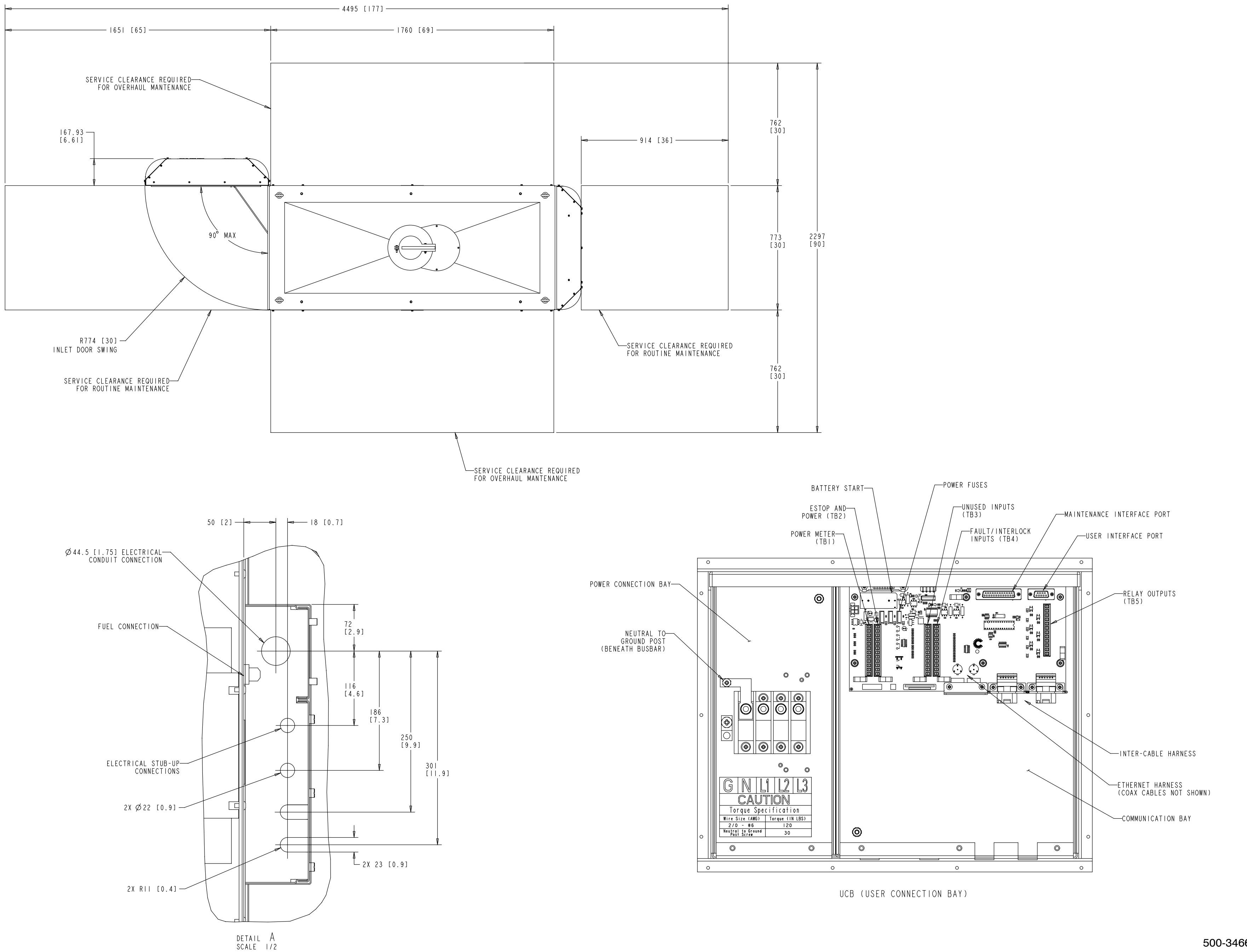
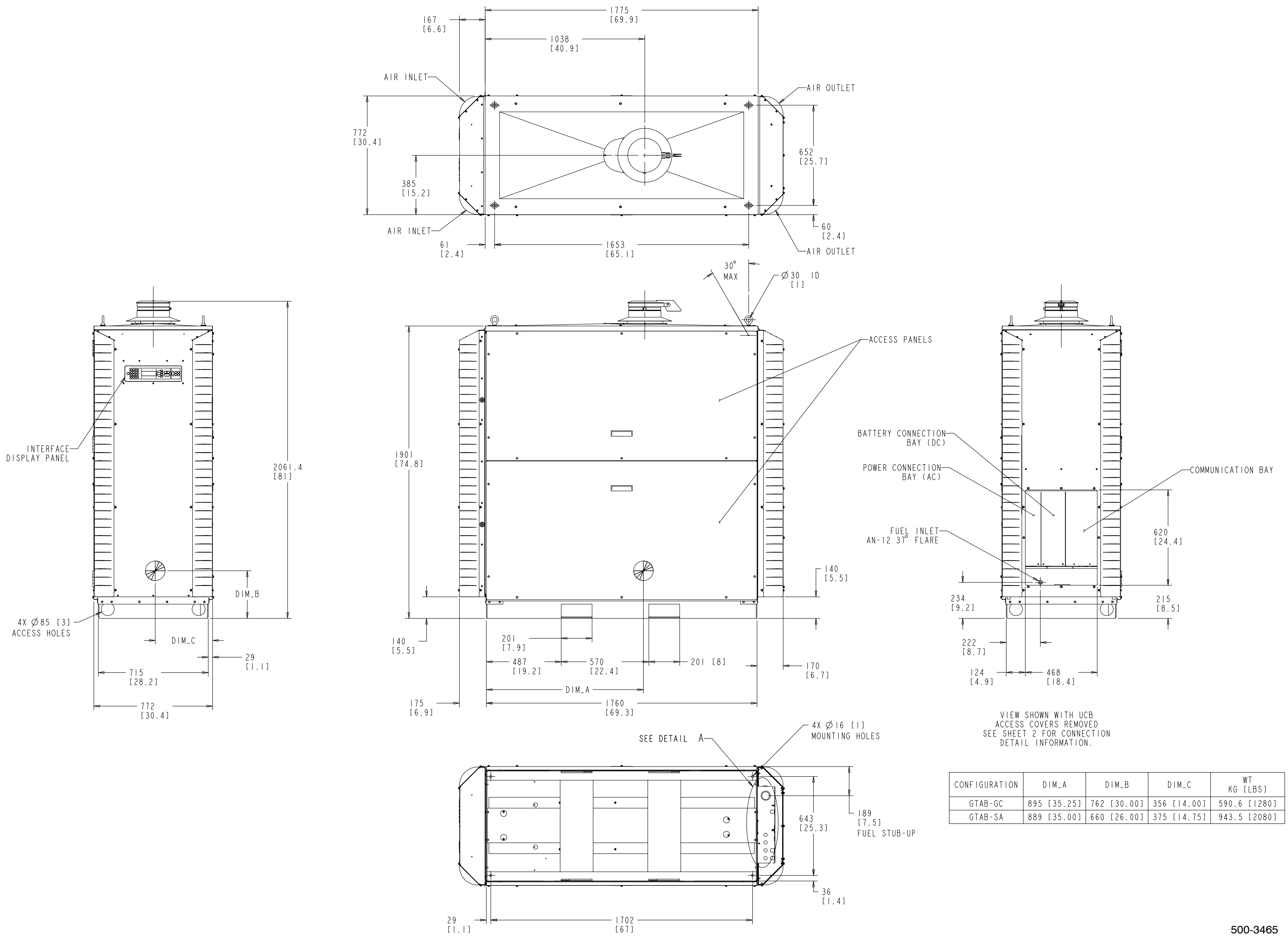


FIGURE 24. MODEL GTAA OUTLINE DRAWING—SHEET 2



CONFIGURATION	DIM_A	DIM_B	DIM_C	WT KG [LBS]
GTAB-GC	895 [35.25]	762 [30.00]	356 [14.00]	590.6 [1280]
GTAB-SA	889 [35.00]	660 [26.00]	375 [14.75]	943.5 [2080]

FIGURE 25. MODEL GTAB OUTLINE DRAWING—SHEET 1

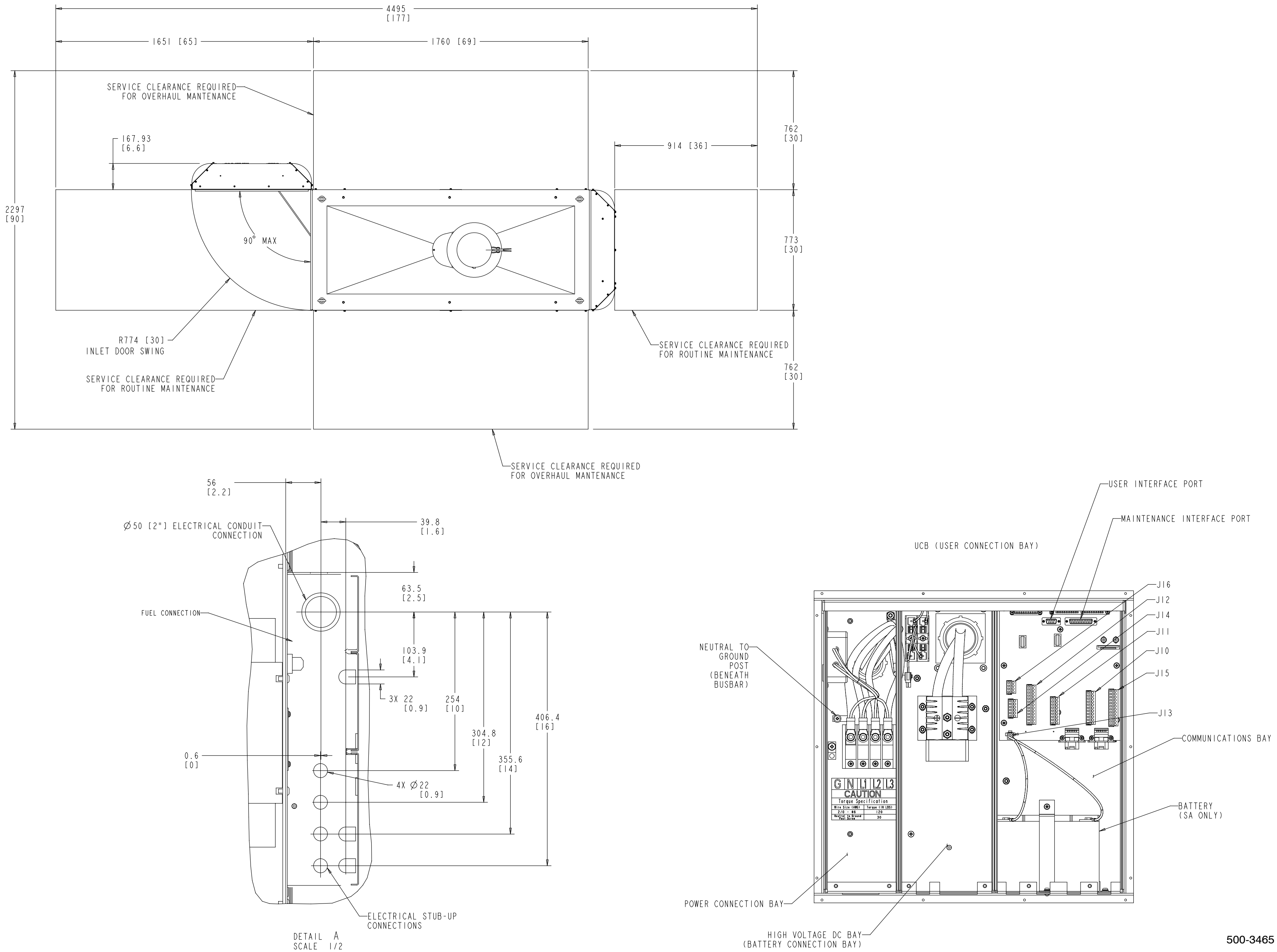


FIGURE 26. MODEL GTAB OUTLINE DRAWING—SHEET 2

Appendix B: Configuring the Microturbine

OVERVIEW

System Connections Prerequisites

Establishing the system settings for the Microturbine is required before operating the system for the first time. All system connections and settings should be completed as noted in this manual.

Adjusting these settings requires familiarity with User Communication and Display Panel operation. See *Appendix D: Display Panel Menus*.

Alternately, all system settings may be established remotely, via optional Remote Monitoring Software.

Establishing the settings, and configuring an operating mode and dispatch mode for the Microturbine in a particular application requires a complete understanding of the user's needs, the electrical output wiring, and the communication connections. For systems which will operate in Stand Alone mode, specifications of the *protected* load(s) must be known. Some dispatch modes may call for an understanding of an external system which may control the Microturbine.

The heat content of the fuel must be known.

Finally, system settings must conform to local governmental regulations and/or utility rules regarding protective relay functions and reverse power flow.

Grid Connect Operating Mode Overview

The Microturbine may be connected in parallel to a utility grid to power local grid connected loads. Employing the Microturbine in this fashion gives the user the capability to reduce the facility power demand by displacing utility power during peak periods. By operating the Microturbine in this Grid Connect mode, the user can insure a seamless supply of power to the local loads whether the Microturbine is on or off.

Stand Alone Operating Mode Overview

When equipped with the Stand Alone Option, the Microturbine may power loads completely independent of other sources of electrical power.

The Microturbine operated in this manner is said to be in the Stand Alone mode and provides independent power to dedicated loads.

Dual Mode Overview

When equipped with the Stand Alone Option, a single Microturbine may be used for BOTH Grid Connect and Stand Alone modes. All the advantages of the Grid Connect mode may be enjoyed. Some loads may be isolated with the Microturbine so that the Microturbine may power these *protected* loads in the event of a grid outage.

Microturbine Operation

The Microturbine requires little or no user input during operation. Refer to the System Operation Manual for detailed descriptions of how to start and operate the Microturbine.

DISPATCH MODES

The Microturbine may be commanded on or off (and Grid Connect may be commanded to different power output levels). These are **dispatch** commands, and there are several schemes by which the Microturbine may be dispatched.

Manual Dispatch

When the Microturbine is commanded on or off (and Grid Connect to an output power level) manually, this is termed the **Block Load** dispatch mode. This is the default dispatch method for a new Microturbine as shipped, and is the configuration resulting from a **Set Defaults** command.

External Switch Dispatch

The External Switch dispatch mode allows an external signal to control the on/off status of the Microturbine (at the commanded output power level for Grid Connect).

Time Of Use Dispatch

When on/off and power output level (Grid Connect mode only) are programmed into the Microturbine, the mode is termed **Time Of Use**. The programming may be done from the display panel or via computer.

Up to twenty individual events may be programmed. An event is a change in the Microturbine demanded output including on/off or set power level. Events may be programmed to occur on any day of the week, and any minute of the day.

Load Following Dispatch (Grid Connect Only)

The Load Following mode provides for the Microturbine to track local electrical loads, supplying only as much power as is demanded locally.

Some facilities have limitations on grid power supply to local loads. These limitations may be commercially imposed as part of the utility power supply contract, or there may be physical limitations of the distribution system hardware.

The Load Following function is designed to limit the grid power flow.

The grid power flow is measured by an external power meter, to an adjustable maximum. If the local load demand rises above this level by an adjustable amount for an adjustable time period, the Microturbine is dispatched to supply the difference (up to its capacity) between the local load and the maximum utility grid power supply set point. Use the **Load Following** function:

- To reduce peak demand charges (where applicable), or
- When power draw from the utility grid is limited by supply equipment capacity, or
- Installed Microturbine capacity exceeds the minimum local load demand (possibility of reverse power flow) and net revenue metering is not allowed by the utility.

Reverse Power Flow Protection (Grid Connect Only)

The Reverse Power Flow Protection mode prevents the Microturbine system from backfiring the grid. If the Microturbine output is greater than the local load demand, the power generated by the Microturbine which is in excess of the local load will flow back to the grid. This may be undesirable for two very specific reasons:

1. Unless net metering is allowed by the utility, the reverse power flow represents an economic loss to the Microturbine user.
2. Most U.S. utilities prohibit reverse power flow and require that the generating equipment cease generation if this condition occurs. The Reverse Power Flow Protection function, when enabled, will initiate a normal shutdown of the Microturbine if reverse power flow occurs for a time period set by the user.

Use the **Reverse Power Flow Protection** function when the host utility:

- Requires reverse power flow protection, or
- Does not allow net revenue metering

When enabled, the Reverse Power Flow Protection function operates independent of and/or simultaneous with any other Load Management Functions.

Reverse Power Flow Protection may be used independent of any other modes, except Load Following if the followed load is other than the connected facility. Refer to the current transformer placement discussion in the Reverse Power Protection Setup section in this appendix.

AutoRestart

The Microturbine includes an automatic restart feature which can be switched on or off by the user. If Auto-Restart is ON, the system will attempt to restart after most system or grid initiated shutdowns. Enabling AutoRestart will increase system availability and is recommended by Cummins Power Generation.

AutoRestart will not attempt to restart the system after a user initiated shut down *unless an* interruption in grid power has occurred. Refer to AutoEnable.

AutoEnable (Stand Alone Only)

The Microturbine, when in Stand Alone mode, includes an automatic output enable feature which may be enabled or disabled by the user. If AutoEnable is ON, the system will automatically begin exporting power as soon as possible after a start. This feature, in conjunction with AutoRestart, will increase system reliability and is normally recommended by Cummins Power Generation.

Sleep (Stand Alone Only)

A Microturbine equipped for Stand Alone operation includes a battery for starting and transient load management. Battery management features include a function to minimize battery drain during long periods of non-use. This function is called *battery* sleep.

BASIC SYSTEM SETTINGS

System Passwords

A user password is required to establish or adjust system settings. The Microturbine is shipped with a default user password which may be changed after the user password is entered.

Since the user with physical access to the Microturbine may be different than the user with access to remote control of the Microturbine, separate user passwords are used for the display and for the remote communications port. The default passwords are noted as follows:

- Display Panel User Password: **87712370**
- User Interface Port (UIP) Password: **USR123P**

The user password may be changed to a unique, user defined password after the current user password is entered. Display panel passwords must be eight digits and they must be numeric. Refer to the Operation Manual.

Date and Time

Set the system date and time to local date and time. Use the System Settings top-level menu, and Set Date sub-menu, enter the current date in MM/DD/YYYY format. Use the Set Time sub-menu, enter the local time in 00:00, 24-hour format.

Display Units (Metric or English)

Select whether the values displayed by the Microturbine Display Panel should appear in English or Metric units. Using the System Settings top-level menu and Display Format sub-menu.

Modes

Select whether the Microturbine system will operate in on of the following modes:

- Grid Connect (GC) mode
- Stand Alone (SA) mode
- Dual mode (both GC and SA)

AutoRestart

Enable or disable the system's ability to automatically attempt to restart after a fault or grid-initiated shutdown.

AutoEnable (Stand Alone Only)

The Microturbine, when in Stand Alone mode, includes an automatic output enable feature which may be enabled or disabled by the user. If AutoEnable is ON, the system will automatically begin exporting power as soon as possible after a start. This feature, in conjunction with AutoRestart, will increase system reliability and is normally recommended by Cummins Power Generation.

Voltage (Stand Alone Only)

In Grid Connect mode, the actual voltage produced by the Microturbine is continuously determined by the grid voltage. No setting is required.

In Stand Alone mode, the nominal system voltage is established in the Stand Alone top-level menu, Voltage submenu. It may be established in one-volt increments from 150 to 480 volts. Nominal system voltage less than 376 volts will limit the power output of the Microturbine.

Frequency (Stand Alone Only)

In Grid Connect mode, the actual frequency produced by the Microturbine is continuously determined by the grid frequency. No setting is required.

In the Stand Alone mode, the nominal output frequency may be established in 0.1 Hz increments from 10 to 60 Hz. Use the Frequency sub-menu of the Stand Alone top-level menu.

PROTECTIVE RELAY SETTINGS

Protective Relay Settings establish voltage and frequency operating limits for the Microturbine. The range of these adjustments are based on what the Microturbine system hardware can tolerate. The settings are adjustable to allow the user to narrow or restrict the operating envelope to local regulatory requirements.

The under voltage and over voltage *functions* are applicable to both Grid Connect and Stand Alone modes, however the *settings* are unique to each operating mode and must be established separately for Grid Connect and Stand Alone. The settings for Grid Connect are found in submenus in the Grid Connect top-level menu, and Stand Alone settings are found in the Stand Alone top-level menu submenus.

The Fast Overvolts and Fast Undervolts functions are applicable only to the Grid Connect mode.

Grid Connect Protective Relay Functions

Utilities commonly require that protective relaying devices be installed with generators connected to their grids. The primary purpose of these devices is to ensure that utility wires de-energized by the utility will not be energized by the local generator.

Historically, these protective relaying devices have been dedicated relays or dedicated solid state power analyzers that provide control signals to disconnecting relays.

Note: The Microturbine has built-in protective relaying functions.

The algorithms used to operate the Microturbine provide excellent protection against islanding of the Microturbine in the absence of utility-supplied grid voltage.

Near short or near open islands are detected within milliseconds through loss of current control. Islands whose loads are more closely matched to the Microturbine output will be detected through one or more of the following protective functions:

- Under Voltage
- Over Voltage
- Over/Under Frequency
- Rate of Change of Frequency

When a Grid Fault Shutdown is initiated by one or more of the protective functions, the following occurs:

- Output power flow ceases within 1.0 msec
- The power output contactor is opened within 100 msec disabling the Microturbine power output from the utility wires and the local load
- Fuel flow to the Microturbine stops

A warm shutdown ensues, during which control power is supplied from the Microturbine generator as it slows down. The warm-down lasts 1 to 2 minutes before the rotor is stopped. The control software does not allow a restart until grid voltage and frequency are within permitted limits.

Reverse Power Flow Protection

The Microturbine may be programmed to initiate a shut down upon detection of reverse power flow at a remote location by installing a pulse-issuing power meter at the remote location. Refer to the section on Reverse Power Protection Setup and External Power Meter Specifications in this appendix.

GRID CONNECT SETUP

Configuring for Grid Connect

To configure the Microturbine for Grid Connect operation, it is necessary to enable the Grid Connect Interlock and then command the system to Grid Connect mode either through the display panel or through the RS-232 commands over the remote communications interface: the user interface port (UIP) or maintenance interface port.

Grid Connect Interlock

The Grid Connect Interlock consists of a pair of 5 volt dry circuit terminals (Figure 27). They are found on the printed circuit board in the Communications bay—Figure 2 (**Model GTAA**) or Figure 3 (**Model GTAB**). A closed circuit between these terminals permits Grid Connect operation, an open circuit disallows Grid Connect operation.

Grid Connect Mode Enable

To enable the Grid Connect mode, the Microturbine must be connected to the live grid and the Grid Connect Interlock closed. To enable the Grid Connect mode from the display Panel requires entering the *User Password*, then navigate to the System Data Menu and the Power Connect submenu. Select *Grid Connect* mode and then press the ACCEPT key. If the Grid Connect Interlock is open, the system will not accept the command and a *User Connection* Error fault will be registered.

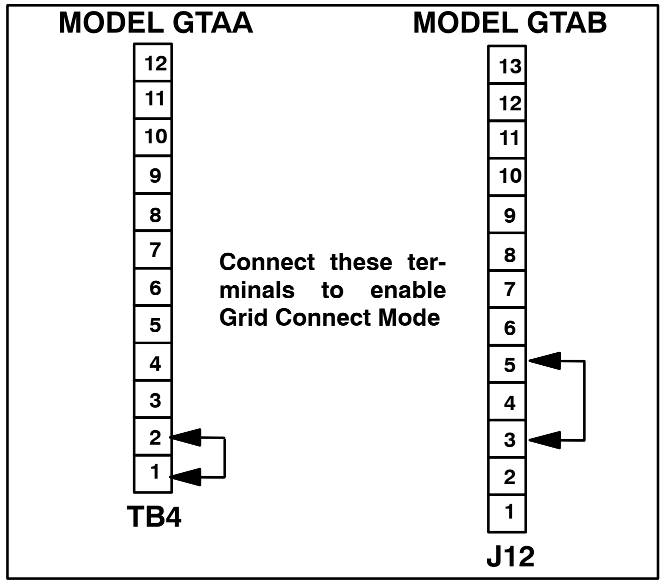


FIGURE 27. GRID CONNECT MODE

Grid Connect Settings

Grid Connect settings are detailed in the paragraphs that follow.

Set Power - Enter the desired output power level in 0.1 kW increments, omitting the decimal. For 57 kW enter “570” and press the ACCEPT key. The system will export power at this level whenever it is in Grid Connect mode, ON, and not in Load Following dispatch mode.

Under Voltage - If the voltage on any phase falls below this setting the delay timer is started. If the voltage has not recovered at the end of the time period, the system will shut down. Adjustable from 360 up to the Over Voltage set point. Default = 428

Under Voltage Delay establishes the time period allowed for any phase voltage to fall below the Under Voltage limit established in Vrms. Adjustable from 0.01 up to 10 seconds in 0.01 second increments. Default = 1.9

Fast Under Volts - The system will cease power export to the grid within 1 msec if any phase voltage drops below Fast Under Voltage for a predetermined time (user adjustable). If the grid voltage re-stabilizes within 1.0 second of the initial under voltage, then the system will resume power export, otherwise the system will shut down. The Fast Under Voltage at which this sequence will be triggered is adjustable here from 0 VAC up to the Under Voltage (established in the Under Voltage section). Default = 264

Fast Under Voltage Delay establishes the time period allowed for any phase voltage to fall below the Fast Under Voltage limit established above. Adjustable from 0.001 to 1.000 second in 0.001 second increments. Default = 0.065

Over Voltage - If the voltage on any phase rises above this setting the timer is started. If the voltage has not subsided by the end of the time period, the system will shut down. Adjustable from 528 down to the Under Voltage set point in1.0 volt increments. Default = 524

Over Voltage Delay establishes the time period allowed for any phase voltage to rise above the Over Voltage limit established above. Adjustable from 0.01 to 10 seconds in 0.01 second increments. Default = 1.9

Fast Over Volts - The system will cease power export to the grid within 1 msec if any phase voltage exceeds Fast Over Volts for a predetermined time (user adjustable). If the grid voltage re-stabilizes within 1.0 second of the initial under voltage, then the system will resume power export, otherwise the system will shut down. The Fast Over Voltage at which this sequence will be triggered is adjustable here from the Over Voltage (established in the Over Voltage section) up to 634 volts. Default = 600

Fast Over Voltage Delay is the number of seconds allowed for Fast Over Voltage condition before the system shuts down. Adjustable from 0.001 to 1.000 second in 0.001 second increments. Default= 0.015

Under Frequency - If the grid frequency falls below this value for the time period established in Under Frequency Delay, the system will shut down. Adjustable from 45.0 Hz to Over Frequency (established in the Over Frequency section), in 0.1 Hz increments. Default = 59.3

Under Frequency Delay is the number of seconds allowed for Under Frequency condition before the system shuts down. Adjustable from 0.01 to 10.00 seconds in 0.01 second increments. Default = 0.07

Over Frequency - If the grid frequency exceeds this value for the time period established in Over Frequency Delay, the system will shut down. Adjustable from Under Frequency (established in the Under Frequency section) to 65.0 Hz, in 0.1 Hz increments. Default = 60.5

Over Frequency Delay is the number of seconds allowed for Over Frequency condition before the system shuts down. Adjustable from 0.01 to 10.00 seconds in 0.01 second increments. Default = 0.07

Frequency Rate of Change - The system will initiate a shut down if the grid frequency changes, up or down, at an excessive rate. This is a part of the active anti-islanding protections built into the Microturbine.

High Impedance Applications

Applications with high impedance due to a utility transformer rated less than 100 kVA, or intervening transformer(s), or very long feeder lines may allow voltage rise at the Microturbine exceeding its limits. To prevent the overvoltage, a transformer with adjustable tap settings (for **Model GTAA** 45 kVA minimum and for **Model GTAB** 75 kVA minimum) must be used to lower the voltage to the Microturbine.

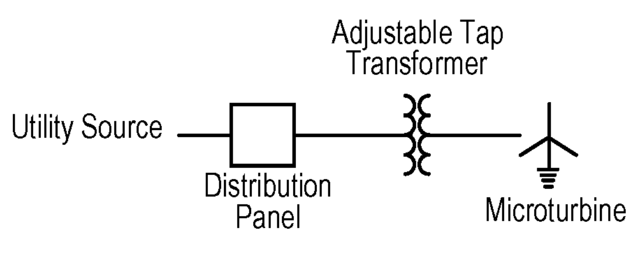


FIGURE 28. ADJUSTABLE TAP TRANSFORMER

Adjustable Tap Settings

If the Microturbine shuts down due to an over voltage event, adjustable tap settings may be used to lower voltage to the Microturbine. The following procedure may be used to determine the adjustable tap setting.

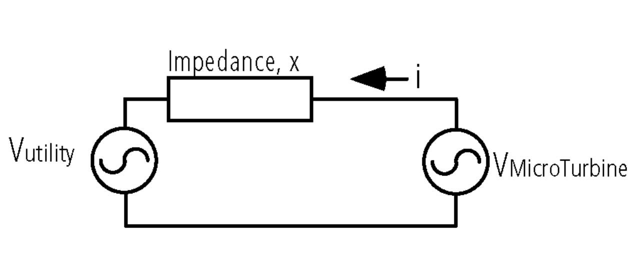


FIGURE 29. HIGH IMPEDANCE APPLICATION

1. Before starting the Microturbine, measure the three line-to-neutral utility voltages (V_u). Average these 3 voltages for V_U.
2. Operate the Microturbine at a power level slightly below the power that caused an overvoltage fault and record the Microturbine's 3 output line-to-neutral voltages and currents. Calculate the average value of the 3 voltages and currents for V_{mt} and i_{mt}, where V_{mt} = Microturbine Voltage and i_{mt} = Microturbine Current.
3. Calculate the resistance component of the impedance, $R = (V_{mt} - V_U) / i_{mt}$.

   For example, at nominal $480V_{rms}$ output, the maximum Microturbine current output at 60 kW is 72A. The full output Microturbine voltage is calculated to be:

   $V_{mtfl} = 480 + (72 \times R \times 1.73)$,
   (V_{mtfl}= Microturbine full load voltage)

   The resultant adjustable tap voltage setting is:

   $V_{tap} = 960 - V_{mtfl}$,
   (V_{tap} = Tap Voltage)

Example - A particular installation experienced an output overvoltage fault when the Microturbine output power was increased. The Microturbine was commanded OFF and the utility voltages were measured and recorded as shown below:

PHASE A - NEUTRAL VOLTAGE	$279V_{rms}$
PHASE B - NEUTRAL VOLTAGE	$275V_{rms}$
PHASE C - NEUTRAL VOLTAGE	$278V_{rms}$

$V_u = (279 + 275 + 278) / 3 = 277.3\ V_{rms}$

Next the Microturbine was restarted and output increased to a point just below the over-voltage trip point (44 kW). The 3 phase currents were measured and recorded as shown below:

PHASE A CURRENT	$56A_{rms}$
PHASE B CURRENT	$51A_{rms}$
PHASE C CURRENT	$52A_{rms}$

$i_{mt} = (56 + 51 + 52) / 3 = 53\ A_{rms}$

The three line-to-neutral voltages were measured under this same 44 kW output and recorded below:

PHASE A - NEUTRAL VOLTAGE	$286V_{rms}$
PHASE B - NEUTRAL VOLTAGE	$288V_{rms}$
PHASE C - NEUTRAL VOLTAGE	$287V_{rms}$

$V_{mt} = (286 + 288 + 287) / 3 = 287\ V_{rms}$

$R = (V_{mt} - V_u) / i_{mt} =$
$(287 - 277.3) / 53 = 0.183$ ohms

$V_{mtfl} = 480 + (72 \times R \times 1.73) =$
$480 + [72 \times 0.183 \times 1.73] = 502.8\ V_{rms}$

$V_{tap} = 960 - V_{mtfl} = 960 - 502.8 = 457.2\ V_{rms}$

The transformer had 2, 2-1/2% taps below normal full capacity (BNFC). The lowest tap voltage was $456V_{rms}$. This tap was connected to the Microturbine and the over-voltage faults were eliminated.

STAND ALONE SETUP

Configuring for Stand Alone

The Microturbine must be equipped with the **Stand Alone Option** to operate in Stand Alone mode.

To configure the Microturbine for Stand Alone operation, it is necessary to enable the Stand Alone Interlock and then command the system to Stand Alone mode either through the display panel or through the RS-232 commands over the remote communications interface: the user interface port (UIP) or maintenance interface port.

Stand Alone Interlock

For Stand Alone operation, the Stand Alone interlock terminals in the Communications Bay must be shorted (Figure 30). They are found on the printed circuit board in the Communications bay—Figure 7 (**Model GTAA**) and Figure 8 (**Model GTAB**).

Stand Alone Mode Enable

To enable the Stand Alone mode, the Microturbine must be powered ON (Battery Isolation Switch set to ON) and the Stand Alone Interlock closed. To enable the Stand Alone mode from the display panel requires entering the *User Password*, then navigate to the System Data menu and the Power Connect submenu.

Select *Stand Alone* mode and then press the ACCEPT key. If the Stand Alone Interlock is open, the system will not accept the command and a *User Connection* Error fault will be registered.

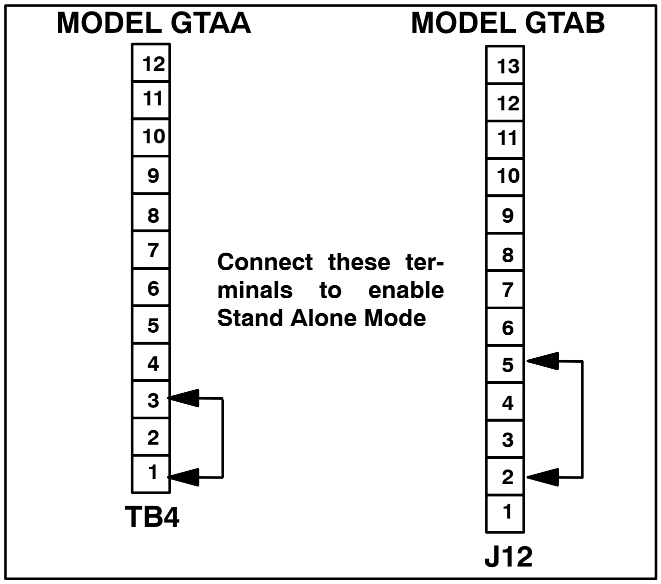


FIGURE 30. STAND ALONE MODE

Stand Alone Settings

Stand Alone settings are detailed in the paragraphs that follow.

Voltage – Voltage establishes the nominal output voltage (line-to-line). Adjustable from 150 to 480 in one volt increments. Nominal system voltage less than 346 will limit the power output of the Microturbine. Default = 480

Frequency – Establishes the nominal output frequency. Adjustable from 10 to 60 Hz in 0.1 Hz increments. Default = 60

Under Voltage – If the voltage on any phase falls below this setting the timer is started. If the voltage has not recovered at the end of the time period, the system will shut down. Adjustable from 0 up to nominal in 1.0 volt increments. Default = 360

Under Voltage Delay establishes the time period allowed for any phase voltage to fall below the Under Voltage limit established above. Adjustable from 10.00 seconds down to 0.01 second in 0.01 second increments. Default = 10

Over Voltage –If the voltage on any phase rises above this setting the timer is tripped. If the voltage has not subsided by the end of the time period, the system will shut down. Adjustable from 528 down to nominal in 1.0 volt increments. Default = 528

Over Voltage Delay establishes the time period allowed for any phase voltage to rise above the Over Voltage limit established above. Adjustable from 0.01 to 10.00 seconds in 0.01 second increments. Default = 10

Under Frequency – If the output frequency falls below this value for the time period established in Under Frequency Delay, the system will shut down. Adjustable from 5 Hz to nominal frequency in 0.1 Hz increments. Default = 45

Under Frequency Delay is the time period allowed for output frequency to fall below Under Frequency (Hz) before the system will shut down. Adjustable from 0.01 seconds to 10.00 seconds in 0.01 second increments. Default = 10

Over Frequency – If the output frequency rises above this value for the time period established in Over Frequency Delay, the system will shut down. Adjustable from 65 Hz down to nominal frequency in 0.1 Hz increments. Default = 65

Over Frequency Delay Is the time period allowed for output frequency to rise above Over Frequency (Hz) before the system will shut down. Adjustable from 10.00 seconds down to 0.01 second in 0.01 second intervals. Default = 10

Ramp Start Settings – The Microturbine may be configured to begin exporting power at less than nominal voltage and frequency and then linearly increase voltage and frequency to nominal over a period of time. All of these parameters are user adjustable in order to optimize the Microturbine's ability to start motor or other loads with large in-rush currents.

Ramp Start Voltage – Ramp Start Voltage establishes the starting voltage for *RampStart*. When the output contactor closes, the system will provide demanded current at this starting voltage and immediately begin increasing the voltage at the rate established below, up to the nominal voltage. Adjustable from 0 to the nominal voltage in one volt increments. Default = 0

Ramp Rate Volts per Second – Ramp Rate Volts per Second establishes the voltage increase rate for *RampStart*. When the output contactor closes, the system will provide demanded current at the voltage established above and immediately begin increasing the voltage at this rate. Adjustable from 3 to 6000 (volts / second) in 1 volt / second increments. Default = 3000

Ramp Start Frequency – Ramp Start Frequency establishes the starting frequency for *RampStart*. When the output contactor closes, the system will provide demanded current at this starting frequency and immediately begin increasing the frequency at the rate established below, up to the nominal frequency. Adjustable from 0 to the nominal frequency in 1 Hz increments. Default = 0

Ramp Rate Hz per Second –When the output contactor closes, the system will provide demanded current at the starting frequency and then immediately begin increasing the output frequency at this rate. Adjustable from 1 to 2000 in 1 Hz increments. Default = 2000

Battery Settings – The Microturbine when equipped with the **Stand Alone Option**, includes a large battery used for unassisted *black* start of the Microturbine and for transient electrical load management.

WARNING ***The battery is heavy. Do not attempt to move, remove, or install a battery without lifting equipment.***

WARNING ***The battery may contain a lethal amount of electricity. Always keep the battery isolation switch OFF and the battery cable unplugged when working with or around the battery.***

The battery is a lead-acid type, completely sealed, and maintenance free. It has been tested and determined to be in compliance with section 173.159(d) of the *United States Department of* Transportation (USDOT) regulation. The battery is excepted from all other shipping requirements of 49 Code of Federal Regulations (CFR), subchapter 173.159, and as of September 30 1995, all shipments are classified as unregulated *nonspillable* wet electric storage batteries. All batteries and shipping containers are marked NONSPILLABLE or NONSPILLABLE BATTERY.

Battery Charge Management

The Microturbine system is designed to keep the battery approximately 80% charged during operation (to allow for sourcing and sinking of current spikes in a Stand Alone circuit), and to then recharge the battery over 90% before shutting down. Normally, the system will take approximately twenty (20) minutes to recharge the battery following an OFF command. There are no settings related to normal charging.

Sleep – The system includes a *sleep* feature to prolong battery charge life. After shutdown, the system will enter the Standby state. If the system is not commanded ON during a user adjustable time period the system will automatically enter a minimum battery drain state called *sleep*.

A sleeping Microturbine must be awakened before any operation (even automatic or remote) is possible. Sleep duration is indefinite, and will preserve battery charge for starting the Microturbine for 6 to 9 months. Battery charge life without sleep is approximately 3 days.

To adjust the time period before the system automatically enters the sleep state after a shutdown, enter the user password, navigate to the Battery Management Menu, and the Auto Sleep Time submenu. Enter the desired delay duration, minimum 1.0 hour and maximum 24 hours. Sleep time is entered in hours, adjustable in 0.1 hour increments.

Equalization Charging – Periodically, the Microturbine will perform an equalization charge cycle to keep the battery in top condition. This equalization charge will take up to four hours. The equalization charge cycle may be disallowed by the user during certain hours of certain days of the week to prevent interference with dispatch schedules.

To prevent equalization charging during certain times of the week, enter the user password, then navigate to the Battery Management Menu, and the Equalization Charge submenu. The first screen provides for day of week choice, the first submenu screen whether equalization charging is or is not allowed. The second submenu establishes the beginning hour for the logic for that day, the third establishes the ending hour for that logic.

Manual Charging – The Battery Isolation switch must be ON. The Microturbine can recharge the battery when in Grid Connect mode. With Manual Charging enabled, a 4-hour equalization charge will be performed, provided that the grid is ok and within the protective relay settings operating envelope.

To enable manual (grid) charging, enter the user password, navigate to the Battery Management menu, and the Manual Charge submenu. Enter an Enable or Disable command and press the ACCEPT key.

DUAL MODE SETUP

Configuring Dual Mode

The Microturbine system settings must be established for BOTH Grid Connect parameters and Stand Alone parameters, since the system will be operating in both modes at different times. See the Installation and Start-up Manual to establish these settings.

Command the system to Dual Mode either through the Display Panel or RS-232 commands over the remote communications interface: the user interface port (UIP) or maintenance interface port. If using the display panel, the user password must be entered. Then navigate to the System Data menu, System Configuration submenu, and the Power Connect submenu, select DUAL MODE and then press the ACCEPT key.

Interlocks

Each mode (Stand Alone and Grid Connect) has a pair of 5 volt dry circuit contact terminals (Figure 31).They are found on the printed circuit board in the Communications bay—Figure 7 (**Model GTAA**) and Figure 8 (**Model GTAB**). When the system is configured for Dual Mode, a low resistance closed circuit between one of these pairs (when the other pair is open) commands the Microturbine to reconfigure to that mode.

Note that when the system configuration setting is Dual mode, operation is prohibited when both interlock circuits open or both interlock circuits are closed. These conditions result in a *User Connection* Error fault.

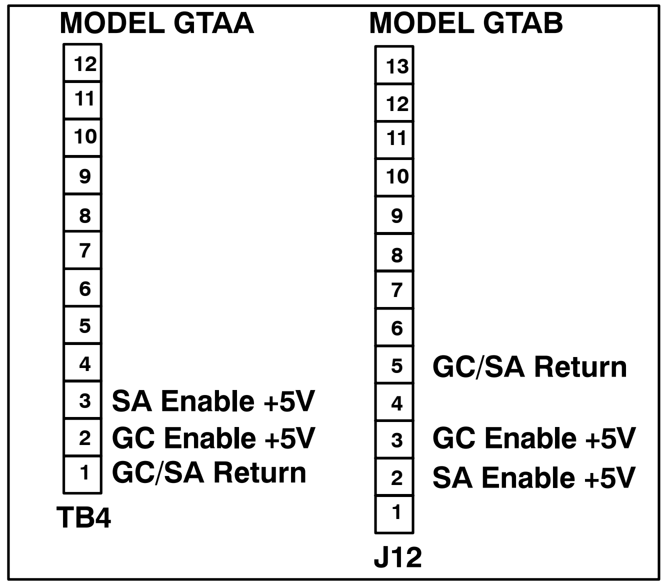


FIGURE 31. DUAL MODE CONNECTIONS

Stand Alone and Grid Connect Interlock Circuits

Switching from Grid Connect to Stand Alone

1. Command the system OFF. The system will immediately cease exporting power, shut off the fuel, and enter the Cooldown state. Upon completion of the cooldown, the system will enter the Standby state.
2. Disconnect the Microturbine and protected loads from the grid.
3. Open the Grid Connect Interlock circuit.
4. Connect the Microturbine to the protected loads, if necessary.
5. Verify that the system is powered (the battery switch is ON).
6. Close the Stand Alone Interlock circuit.
7. Press the BATT START key on the display panel.
8. Press and hold the INTERLOCK key on the display panel, and then press the START key. The system will transition through the start states and after the run, when the engine has warmed up and the battery has been charged to a base state-of-charge (SOC) of at least 60% the system will be ready to load.
9. Press and hold the INTERLOCK key on the display panel, and then press the ENABLE key.

Note: Steps 7, 8, and 9 may occur automatically depending on the Microturbine dispatch mode.

Switching from Stand Alone to Grid Connect

1. Command the system OFF The system will immediately cease exporting power, and may enter the Battery Charge state. Upon completion of the battery charging (up to 30 minutes, the system will enter the Cooldown state (up to two minutes) and then enter the Standby state.
2. Open the Stand Alone Interlock circuit.
3. Connect the Microturbine (and protected loads, if necessary) to the grid.
4. Close the Grid Connect Interlock circuit.
5. Press and hold the INTERLOCK key on the Display Panel, and then press the START key. The system will transition through the start and warm-up states, and then begin exporting power per the Grid Connect configuration settings.

Note: Step 5 may occur automatically depending on the Microturbine dispatch mode.

Automatic Dual Mode Controller

The above transition steps can be accomplished entirely automatically through the use of the Automatic Dual Mode Controller. Consult your Cummins Power Generation Dealer for details.

Default Mode

The Microturbine ships in the DISABLED mode, and neither of the mode permissive terminal pairs is connected. No operation is possible.

Normally, the Microturbine ***remembers*** its last mode setting through power interruptions. A Microturbine which loses its connection to the grid or when the battery isolation switch is turned off, will safely shut down if running, and remain in the OFF state until power is restored.

When the system completes its basic self test, it configures itself for the same operating mode that was active when power was lost.

REMOTE SWITCH SETUP

An external, 5 volt, dry contact switch or timer may be used for remote dispatch.

On **Model GTAA** the switch is connected to terminals 3 and 4 on TB1 and on **Model GTAB** to terminals 4 and 5 on J12 (Figure 32) in the Communications Bay. The Remote Switch terminals are enabled via the Microturbine Display Panel.

TIP: When the Remote Switch is enabled, the Microturbine cannot be commanded ON or OFF from the Display Panel. The remote switch must be used for ON and OFF commands.

To Connect a Remote Switch

Connect a Remote Switch as follows:

1. Shut down the Microturbine and disconnect power.
2. Remove the cover from the Communications Bay.
3. Connect the two poles of the switch to TB1 (**Model GTAA**) or J12 (**Model GTAB**). Polarity does not matter.
4. Replace the cover.
5. If configuring the Microturbine system from the display panel:
    a. Enter the User Password in System Data menu
    b. Remain in System Data
    c. Navigate to System Configuration submenu 3/7
    d. Navigate to Start Input submenu 3/5.
    e. Press the fourth line select key from the top. The line should begin flashing. (If not, then the password is probably not entered.)
    f. Press the (+) key in order to select from four different options available (User; Remote; Remote SA User GC; Remote GC User SA)
    g. Press the ACCEPT key.

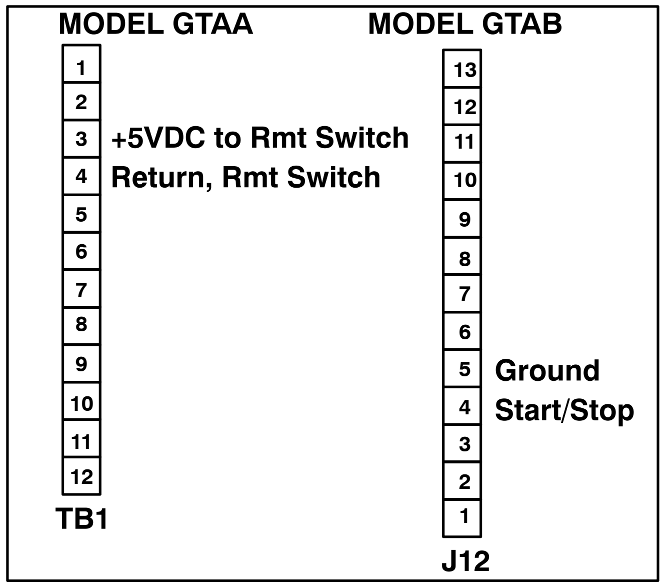


FIGURE 32. REMOTE SWITCH CONNECTIONS

REVERSE POWER PROTECTION SETUP

To enable *Reverse Power Flow Protection* requires installation of an external power meter, specified and connected to the Microturbine; see External Power Meter Specifications in this Addendum.

The Microturbine alone cannot know where the utility ends and the facility begins. Definition of this point is the job of the external power meter, and the point is determined by the location of the power meter's current transformers.

For Reverse Power Flow Protection, the Power Meter's current transformers **MUST** be located between the utility service entrance and the Microturbine (Figure 33). If this location conflicts with the desired location for Load Following, the functions are incompatible.

To set up the Microturbine for Reverse Power Flow Protection, proceed as follows:

1. Shut down the Microturbine; disconnect power.
2. Remove the cover from the Communications Bay.
3. Connect the 4 wires of the meter to TB1 (**Model GTAA**) or J12 (**Model GTAB**) per instructions in *External Power Meter Specifications*. See Figure 34.
4. Replace the cover.
5. If configuring the Microturbine system from it's Display Panel:
   a. Enter the User Password.
   b. Navigate to Load Management Menu 7 of 11 and adjust the menu items per the table noted below:

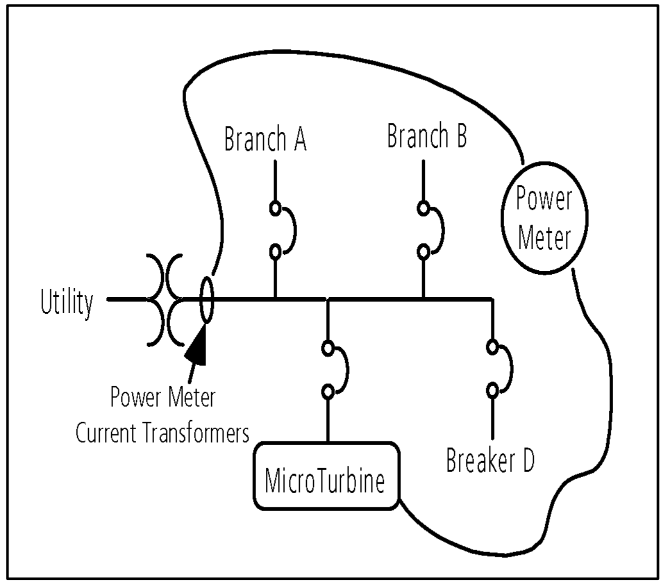


FIGURE 33. CORRECT PLACEMENT OF REVERSE POWER PROTECTION CURRENT TRANSFORMER

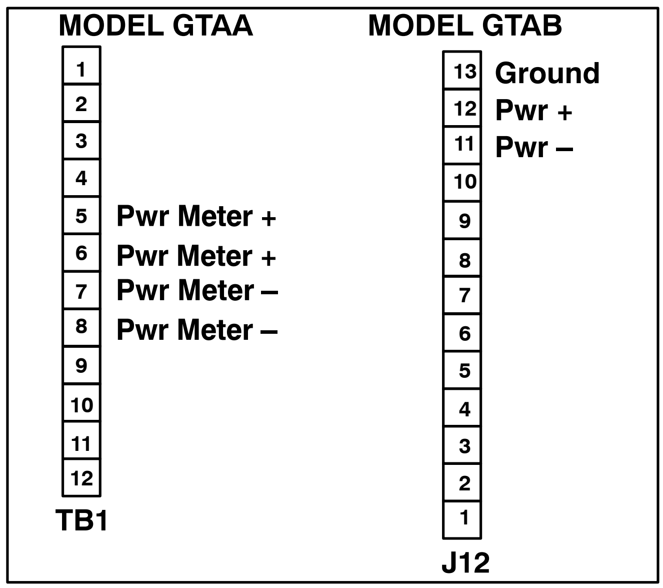


FIGURE 34. CONNECTIONS FOR REVERSE POWER PROTECTION

LOAD MANAGEMENT MENU		PARAMETER DESCRIPTION	PARAMETER VALUE	DEFAULT
1/5	RevPwrPrtct <select> <seconds>	Reverse Power Protection Mode Enable/Disable Duration before Shutdown	 1 = Enabled 0 to 120 Seconds	 0 120
2/5	Utility/Pwr	Load Following Utility Power Limit	Not Applicable	0
3/5	Response Time <seconds>	Time period over which power measurements are averaged to smooth out transients	1 to 120 Seconds	1
4/5	MinPwrShutoff	Minimum Microturbine Power Set Point	Not Applicable	0
5/5	Meter <Wh/pulse>	Power Meter Scaling Constant (@ Microturbine terminals)	0 to 50.00 Watt-hours / pulse	0.00

LOAD FOLLOWING SETUP

To start the Microturbine in Load Following mode requires installation of an external power meter. Refer to the *External Power Meter Specifications* section.

The Microturbine is a demand loaded system. In Load Following mode the demand signal is produced by the external power meter. Loads on the load side of the power meter current transformer location will produce demand signals, loads on the utility side will not. The Microturbine power also flows through the power meter. A feedback loop is used to bring the power down to the set value.

This meter measures the power flow at a point remote from the Microturbine and provides +PULSE (forward power flow) and -PULSE (reverse power flow) signals at a rate proportional to the power flow at the measuring point.

For example, in the following illustration, the Microturbine power output demand will be determined by the loads on Branches B and D only. Branch A or C loads would have no effect. The Microturbine may be connected at either Breaker location, B or D and the power output demand will still be determined by the flow through the power meter current transformers.

NOTE: The Power Meter MUST be installed between the Microturbine and the utility entrance.

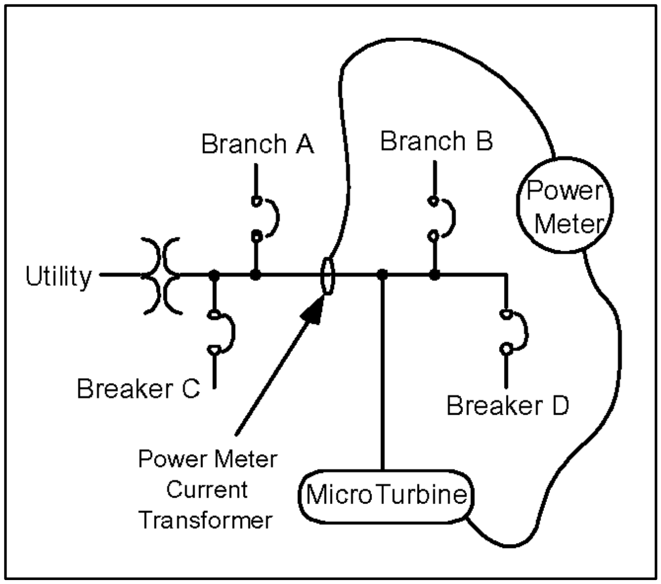


FIGURE 35. POWER METER

To setup Load Following:

1. Shut down the Microturbine; disconnect power.
2. Remove the cover from the Communications Bay.
3. Connect the 4 wires of the meter as illustrated in the Reverse Power Protection Setup section.
4. Replace the cover.
5. If configuring the Microturbine system from it's Display Panel:
   a. Enter the User Password.
   b. Navigate to Load Management Menu 7 of 11 and adjust the menu items per the table noted below:

LOAD MANAGEMENT MENU		PARAMETER DESCRIPTION	PARAMETER VALUE	DEFAULT
1/5	RevPwrPrtct <select> <seconds>	Reverse Power Protection Mode Enable/Disable Duration before Shutdown	0 = Disabled 1 = Enabled 0 to 120 Seconds	 0 120
2/5	Utility/Pwr <power>	Load Following Utility Power Limit	–1000 to + 1000 kW	0
3/5	Response Time <seconds>	Time period over which power measurements are averaged to smooth out transients	1 to 120 Seconds	1
4/5	MinPwrShutoff <power> <minutes>	Minimum Microturbine Power Set Point Duration of output above/below set point before starting/stopping	0 to 2,000,000 kW 1 to 15 minutes	0 15
5/5	Meter <Wh/pulse>	Power Meter Scaling Constant (@ Microturbine terminals)	0 to 50.00 Watt-hours / pulse	0.00

TIME OF USE SETUP

External hardware is not required to dispatch the Microturbine based on Time of Use. Enabling the Time of Use functions consists of programming the Time of Use events and then enabling the Time of Use function. Time of Use may be used in either Grid Connect or Stand Alone mode.

If configuring the Microturbine system from its display panel:

1. Enter the User Password
2. Navigate to Load Management Menu
3. Adjust the menu items 1 through 5 per the table below.
4. Navigate to Time of Use Menu and adjust menu items 1 through 4 per the table below for each of up to 20 events, for up to 10 Microturbines in a MultiPac. Enter Day = 0 for unused events.

LOAD MANAGEMENT MENU		PARAMETER DESCRIPTION	PARAMETER VALUE	DEFAULT
1/5	RevPwrPrtct <select> <seconds>	Reverse Power Protection Mode Enable/Disable Duration before Shutdown	0 = Disabled 1 = Enabled 0 to 120 Seconds	0 120
2/5	Utility/Pwr <power>	Load Following Utility Power Limit	Not Applicable	0
3/5	Response Time <seconds>	Time period over which power measurements are averaged to smooth out transients	Not Applicable	1
4/5	MinPwrShutoff <power> <minutes>	Minimum Microturbine Power Set Point Duration of output above/below set point before starting/stopping	Not Applicable	0 15
5/5	Meter <Wh/pulse>	Power Meter Scaling Constant (@ Microturbine terminals)	Not Applicable	0.00

LOAD MANAGEMENT MENU		PARAMETER DESCRIPTION	PARAMETER VALUE	DEFAULT
1/20	Event <select>	A time of Use event is a particular time on a particular day of the week	0 to 20	0
1/4	Day <option>	Numeric day of the week for the even to execute	Inactive = 0* Sunday = 1; Saturday = 7	0
2/4	Time <option>	Time of day for the event to execute Format: HHMM	0000 to 9999	0000
3/4	Command <option>	Start Command for the event	Stop = 0 Start = 1	0
5/5	Power Demand <option>	Power output command for the event Format: do not enter decimal	0 to 2,000,000 kW	0

*An entry of “0” (zero) resets the event to default values and removes it from the execution list.

EXTERNAL POWER METER SPECIFICATIONS

Load Following and Reverse Power Flow

The *Load Following* and *Reverse Power Flow* functions require the installation of a 3-phase power meter at a location remote from the Microturbine. The Microturbine hardware and software are designed to accept signals from a pulse output power meter such as the ***ABB Power+ Alpha*** meter with 6 output relay board option (KYZ) relay option. Connect the the meter to TB1 (**Model GTAA**) or J12 (**Model GTAB**). See Figure 36.

This type of power meter accumulates electrical energy watt-hours and periodically issues a voltage pulse when the accumulated watt-hours reach a certain level. Total power flow over a period of time is determined by counting the pulses. Power flow in the forward direction (towards the loads) is measured as PWR+. Also, power flow in the reverse direction is measured as PWR-. A power meter which issues both PWR+ and also PWR- signals is necessary.

Power Signal Specifications

Parameter	Units	Value
Pulse Width	Msec	>= 1.67
Pulse Rate	HZ	<= 600

The pulse signal is seen at the Microturbine as a closing and opening of a set of 5 VDC, dry circuit rated contacts.

Scaling Factor

Each power meter has an internal calibration factor supplied with the electronics.

This internal calibration factor may have to be modified by multiplicative factors associated with the current and potential transformers employed between the power meter and the power wiring. Thus, the overall calibration factor seen by the Microturbine is as follows:

$$K_e = K_h / (P/R) \times CTR \times PTR / DIV$$

Where:

K_e = Scaling constant for pulses entering the Microturbine terminals, W-h / pulse

K_h = A typical K_h is 1.8 W-Hr per revolution; power meter internal calibration factor, W-h / revolution (usually found on meter face)

CTR = Current transformer ratio (current at power meter/current in lines); Example: a 2000 A to 5 A current transformer would have a CTR of 2000 / 5 = 400

PTR = Potential transformer ratio (voltage at power meter/voltage at bus); Example: a 480 V to 120 V potential transformer would have a PTR of 480 / 120 = 4

DIV = Any other division ratio applicable to the power meter

P/R = Pulse per revolution (usually found on meter face)

K_e is the scaling constant that should be entered into the display/controller. The power meter internal calibration factor, current transformer ratio and voltage transformer ratio must be such that the scaling constant falls in the range 0 - 50.000

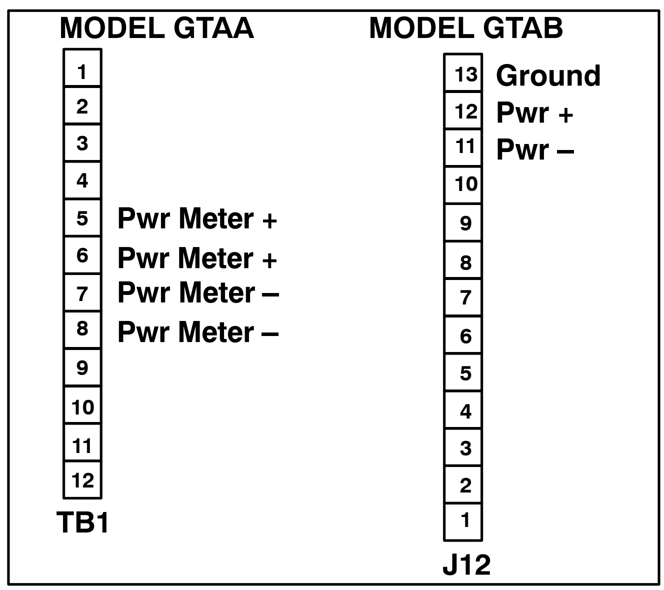


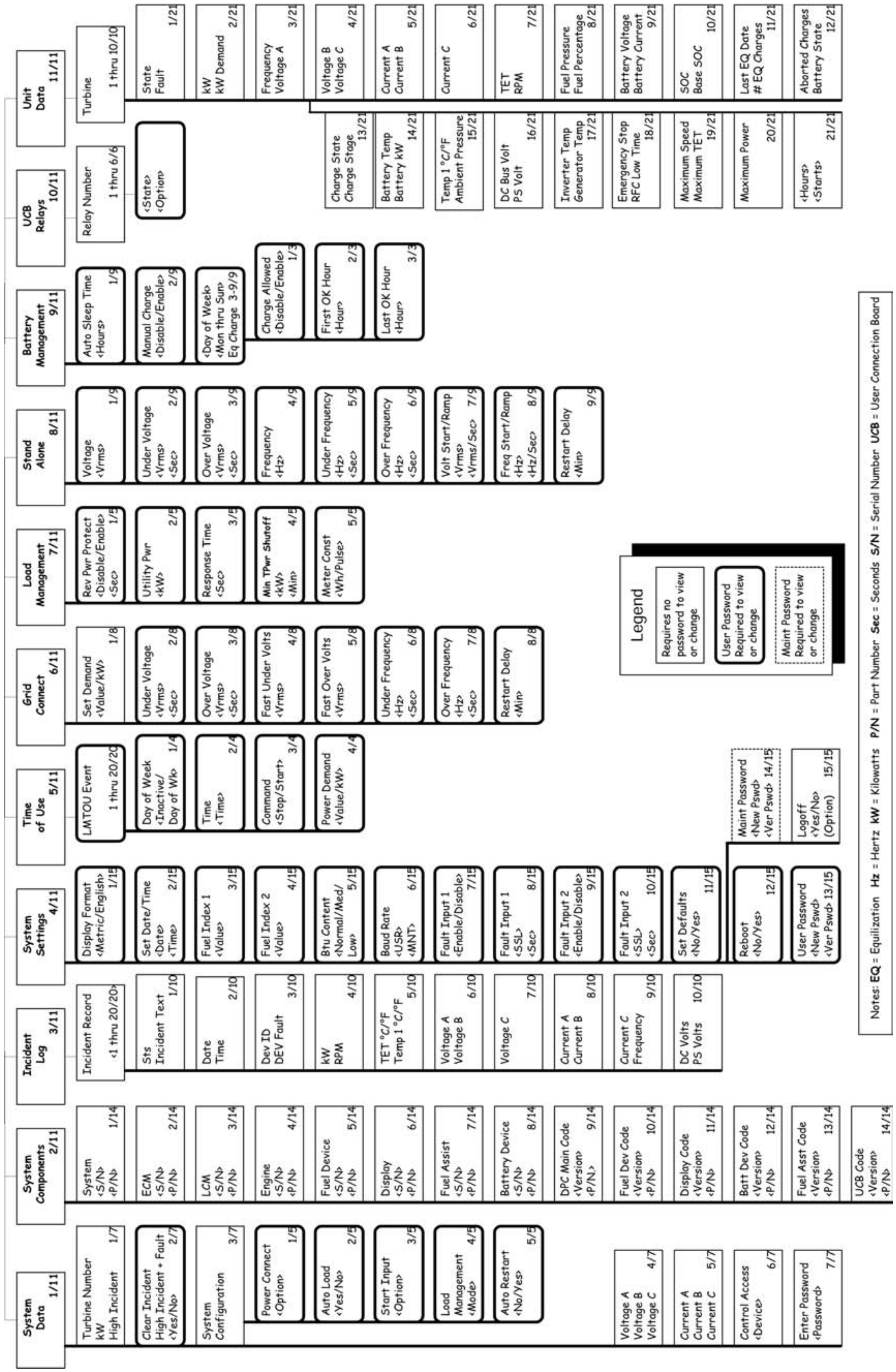
FIGURE 36. CONNECTIONS FOR REVERSE POWER PROTECTION

Appendix C: Specifications

	GTAA	GTAB
Electrical Power (3-Ph)	30 kW	60 kW
Voltage (Frequency)—Grid Connect	400-480 VAC (45-65 Hz)	400-480 VAC (45-65 Hz)
Voltage (Frequency)—Stand Alone	150-480 VAC (10-60 Hz)	150-480 VAC (10-60 Hz)
Power (Current) / Phase—Stand Alone	10 kW (46 amps)	20 kW (100 amps)
Maximum (10-Sec) Current / Phase—Stand Alone	54 amps	110 amps
Full-Load Fueling Rate	440,000 kJ (417,000 Btu)	918,000 kJ (870,000 Btu)
Useable Exhaust Heat (ISO Conditions)	305,000 kJ (290,000 Btu)	571,000 kJ (541,000 Btu)
Exhaust Temperature	261-315° C (500-600° F)	225-338° C (490-640° F)
Maximum Design Exhaust Temperature	315° C (600° F)	370° C (700° F)
Maximum Exhaust Back Pressure	32 kPa (8 in WC)	32 kPa (8 in WC)
Exhaust Gas Flow	17 NM^3/ MIN (575 SCFM)	28 NM^3/ MIN (900 SCFM)
Maximum Inlet Air Restriction (Pressure Drop)	0.125 kPa (0.5 in WC)	0.125 kPa (0.5 in WC)
Engine Air Flow	15.6 NM^3 / MIN (550 SCFM)	26.6 NM^3 / MIN (900 SCFM)
Electronics Cooling Air Flow (SA & GC)	11.3 NM^3 / MIN (400 SCFM)	9.6 NM^3 / MIN (330 SCFM)
Battery Module Cooling Air Flow (SA)	5.6 NM^3 / MIN (200 SCFM)	8.4 NM^3 / MIN (290 SCFM)
Fuel Gas Compressor Cooling Air	17 NM^3 / MIN (600 SCFM)	–
Maximum Cooling Air Temperature	50° C (122° F)	50° C (122° F)
Minimum Cooling Air Temperature	-20° C (-4° F)	-20° C (-4° F)

Appendix D: Display Panel Menus

Display Panel Menu Hierarchy



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