Capstone Turbine Corporation • 21211 Nordhoff Street • Chatsworth • CA 91311 • USA
Telephone: (818) 734-5300 • Facsimile: (818) 734-5320 • Website: www.microturbine.com

Technical Reference

Grid Connect Operation – Capstone Model C30 and C60/C65

Introduction

This document presents information on operating the Capstone MicroTurbine in Grid Connect mode. Grid Connect mode allows the MicroTurbine to be connected in parallel with the electric utility grid to maximize power efficiency during peak load periods.

Grid Connect mode gives the user the capability to reduce the facility power demand by supplementing electric grid power during peak periods. When a grid interruption does occur, the system can start automatically and resume supplying electricity to connected loads once grid power returns. In Grid Connect, the MicroTurbine is a current source only - the MicroTurbine synchronizes to the electric utility for both voltage and frequency reference. The MicroTurbine can be used to provide base load power or shave peak power based on loads or user commands.

Features

The MicroTurbine in Grid Connect operation allows electric utilities to expand generating capacity in small increments. This optimizes current infrastructure and reduces the need to upgrade specific site capacity and lowers overall costs. Grid Connect capabilities also include programmable peak shaving functions, which automatically configure the MicroTurbine to operate on a timed schedule or to follow local loads, thereby reducing peak demand charges. These special features are described as *Time of Use* and *Load Following* dispatch modes. Time of Use supplies variable power levels at selected times to meet user load demand. Load Following tracks local electrical loads to supply power on an as-needed basis. An additional feature, *Reverse Power Flow Protection,* prevents the MicroTurbine system from backfeeding the grid. Implementation of Load Following mode and Reverse Power Flow Protection requires installation of an external power meter and/or a timer or switch. The external power meter provides information to the MicroTurbine on power flow at a point between the MicroTurbine and the grid power supply.

Power Specifications

The full-load power output in Grid Connect mode for the Model C30 is 360-528 VAC (45-65 Hz, 3-phase), 46 A_{RMS} per phase and for the Model C60/C65 is 360-528 VAC (45-65 Hz, 3-phase), 100 A_{RMS} per phase. For complete electrical performance ratings, see the Model C30 and Model C60/C65 Electrical Technical Reference (410000 and 410001). For details on electrical interconnection, see the Electrical Interconnection Technical Reference (410009).

Other Modes

The MicroTurbine can operate in two other modes: Stand Alone, and Dual Mode. Stand Alone operation utilizes a large internal battery, which stores energy for starting the MicroTurbine when disconnected from the electric utility grid. Dual mode combines Stand Alone and Grid Connect modes, so the MicroTurbine is able to maximize power availability utilizing the grid when available, and Stand Alone during a utility outage. Refer to the Stand Alone Technical Reference (410028) and Dual Mode Controller Technical Reference (410039) for details.

Configuring Grid Connect Operating Mode

Overview

Grid Connect mode requires the user to electrically connect the MicroTurbine to the local utility. Once this is complete, simply apply utility grid power to begin operation. Refer to the Electrical Installation Technical Reference (410009) manual for detailed information on the interconnection requirements.

After utility grid interconnections have been made, the following actions are performed:

- Electrically close the Grid Connect contacts in the communications bay (see *Contact Terminal Location* section)
- Configure the software for Grid Connect operation using one of two modes of access:
  - User input – through the local display panel or CRMS
  - Remote input – CRMS through either the RS-232 User or Maintenance port
- Enter an initial system power demand value
- (Optional) Configure a Load Management mode to optimize performance. An external power meter must be connected when selecting Load Following Mode (Refer to the *Configuring the Dispatch Mod*es section for more details).
  - *Normal* mode (default) utilizes electric utility grid power in excess of MicroTurbine base power
  - *Load Following* mode utilizes MicroTurbine power in excess of base power supplied by the utility grid (when required by external loads)
  - *Time of Use* mode utilizes pre-determined settings to select the hours and power demands for MicroTurbine operation.
- (Optional) Enable Reverse Power Flow Protection, if required. An external power meter must be connected (Refer to *Reverse Power Flow Protection* section).
- (Optional) Select Auto Restart mode to automatically attempt a restart after an incident-driven fault.
- (Optional) Select MultiPac mode to combine MicroTurbine power in series with any of the above dispatch modes.
- (Optional) Enable Fast Transfer Mode to decrease the transition time to Grid Connect mode.
- Issue a Start command to commence MicroTurbine operation.

Hardware Configuration

Contact Terminal Locations

The User Connection Board (UCB) located in the communications bay allows for low-resistance closed-loop circuit connections on 5-volt dry circuit contact terminals. Contact terminal connections are internal to the MicroTurbine, with the exception of external switch contacts, which may be remotely connected to any external device (e.g, PLC or switch):

- Grid Connect Interlock – Establishes Grid Connect mode of operation
- External Switch – Enables hardware interlock for remote turbine communication. Software settings must also be established (see "Configuring the Dispatch Modes")

Figures 1 and 2 show the Model C30 and Model C60/C65 contact terminal locations.

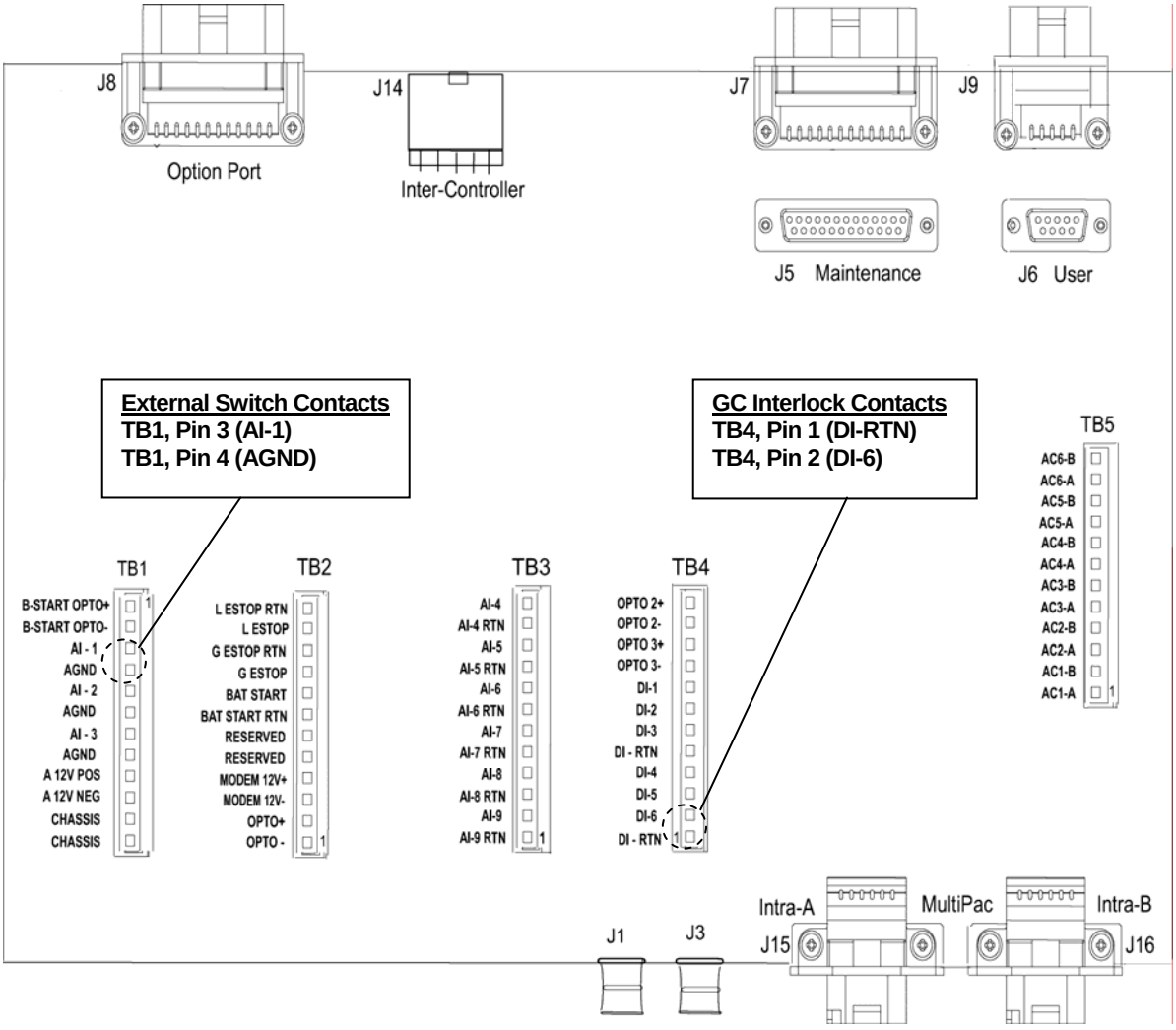


Figure 1. Grid Connect Contact Terminal Locations (Model C30)

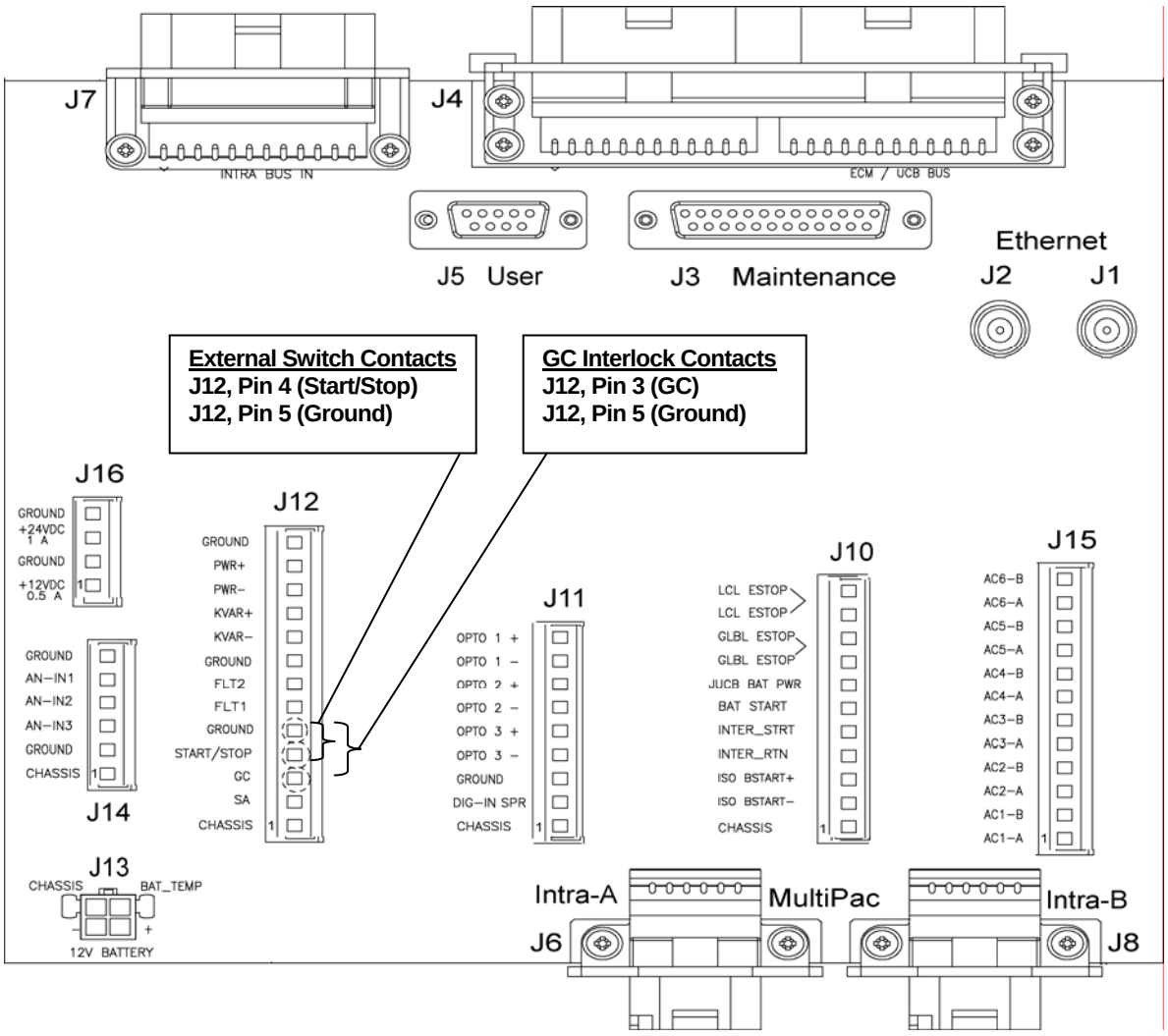


Figure 2. Grid Connect Contact Terminal Locations (Model C60/C65)

Grid Connect Operation

Initial Configuration

Configure the MicroTurbine system to recognize Grid Connect mode using CRMS or the display panel. If using remote access, only CRMS is available.

- CRMS: Select *Settings* > *Control Settings*, and set the Power Connect slider to Grid Connect. Return to the main screen and enter an initial Power Demand (kW) value.
- Display panel: Enter the user password (default is **87712370**), and navigate as follows - *System Data* > *System Configuration* > *Power Connect*, and select Grid Connect option. In the Grid Connect menu, enter the desired power (kW) using the Set Demand option.

Starting the Grid Connect System

An initial Start command must be received by the MicroTurbine to initiate operations, even if the system is configured for use with Load Management dispatch modes. If an external switch is used, wiring connections to the attaching device must be established before MicroTurbine software is configured to enable the switch (see "*Configuring the Dispatch Modes – External Switch*").

- CRMS: Press the green START button.
- Display panel: Press and hold the INTERLOCK and START buttons simultaneously. If the MicroTurbine has been configured with a remote start/stop switch, set the switch to START or ON to start the system.

If the Grid Connect Interlock is open when a START command is issued, the system will accept the Start command but post a *GC Interlock* fault, prohibiting the start.

Select a Load Management Mode (option)

Configure the desired load management mode for most efficient operation: Normal (default), Time of Use, or Load Following.

- CRMS: From the menu, select *Settings* > *Load Management Settings*, and set the slider to *Time of Use* or *Load Management*. If Time of Use is selected, navigate to the *Time of Use Settings* screen. No adjustment is made for the *Normal* (default) mode.
- Display panel: Navigate as follows - *System Data* > *System Configuration* > *Load Management*, and then select *Normal, Time of Use* or *Load Following*. If Time of Use mode is selected, configure user parameters from the *Time of Use* menu. If Load Following mode is selected, configure user parameters from *Load Management* menu.

Select Auto Restart Mode (option)

Select Auto Restart to allow the system to automatically attempt a restart after an incident-driven shutdown.

- CRMS: From the menu, select *Control Settings*, and set Auto Restart toggle to ON.
- Display panel: Navigate as follows - *System Data* > *System Configuration* > *Auto Restart,* and select YES.

Select MultiPac Mode (option)

Configure the MicroTurbine to operate in MultiPac mode to combine output power efficiently to external loads. Refer to the MultiPac Technical Reference (410032) for more details.

- CRMS: From the menu, select *Settings* > *MultiPac Settings*, and set the MultiPac Enable setting to ENABLE. Configure the turbine number in the MultiPac system (Master = 1).
- Display panel: Navigate as follows - *System Data* > *System Configuration* > *MultiPac*, and then select ENABLE.

Select Fast Transfer Enable mode (option)

Configure Fast Transfer mode for transition periods when the grid is returns to operation. Normal setting for Fast Transfer operation is Auto. If set to Manual and Auto Restart has been enabled, a manual Start operation must be performed by the user. The Reconnect Delay period determines the amount of time required to verify the grid is in good working condition.

- CRMS: From the menu, select *Settings* > *Control Settings*, and set the GC Enable setting to either Auto or Manual. Select the Reconnect Delay time.
- Display panel: Navigate as follows – *Grid Connect* menu*,* and then select the GC Enable mode option (Auto/Manual) and the GC Reconnect Delay option (<time>).

Stopping a Grid Connect System

The normal process to stop MicroTurbine operation can be performed at any time. The process includes a cooldown cycle, which can last up to 10 minutes, depending on the operating temperature at shutdown. During this cycle, the power output is reduced and the fuel supply is shut off, but the MicroTurbine continues to rotate to dissipate excess heat. A restart can be attempted at any time during a cooldown period. In Grid Connect operation, an OFF command will override any dispatch mode settings, and is stored by the system.

- CRMS: From the menu, click the red STOP button so that the button changes to START and appears *green.*
- Display panel: Press and hold the INTERLOCK and STOP buttons simultaneously. If the MicroTurbine has been configured with a remote START/STOP switch, set the switch to STOP or OFF to stop the system.

Initiating an Emergency Stop

WARNING	Repeated use of the optional Emergency Stop switch will result in damage to the MicroTurbine. Use only in emergency situations.

If an optional emergency stop (E-stop) has been installed, the E-stop switch may be activated. Activating E-stop immediately shuts off the fuel and electrical output. This action also causes the compressor bypass valve to open, venting the compressed air out of the MicroTurbine and causing it to coast to a stop. After an emergency stop, the power to the MicroTurbine must be turned off for 30 seconds before a restart can be attempted. Emergency stops should NEVER be used for routine shutdowns. Emergency stops increase stress on the system components and will result in reduced service life of the MicroTurbine.

System States

Grid Connect mode passes through a set of system states during a normal cycle. These states are described in the section below. A simple block diagram illustrating Grid Connect system states is shown in Figure 3.

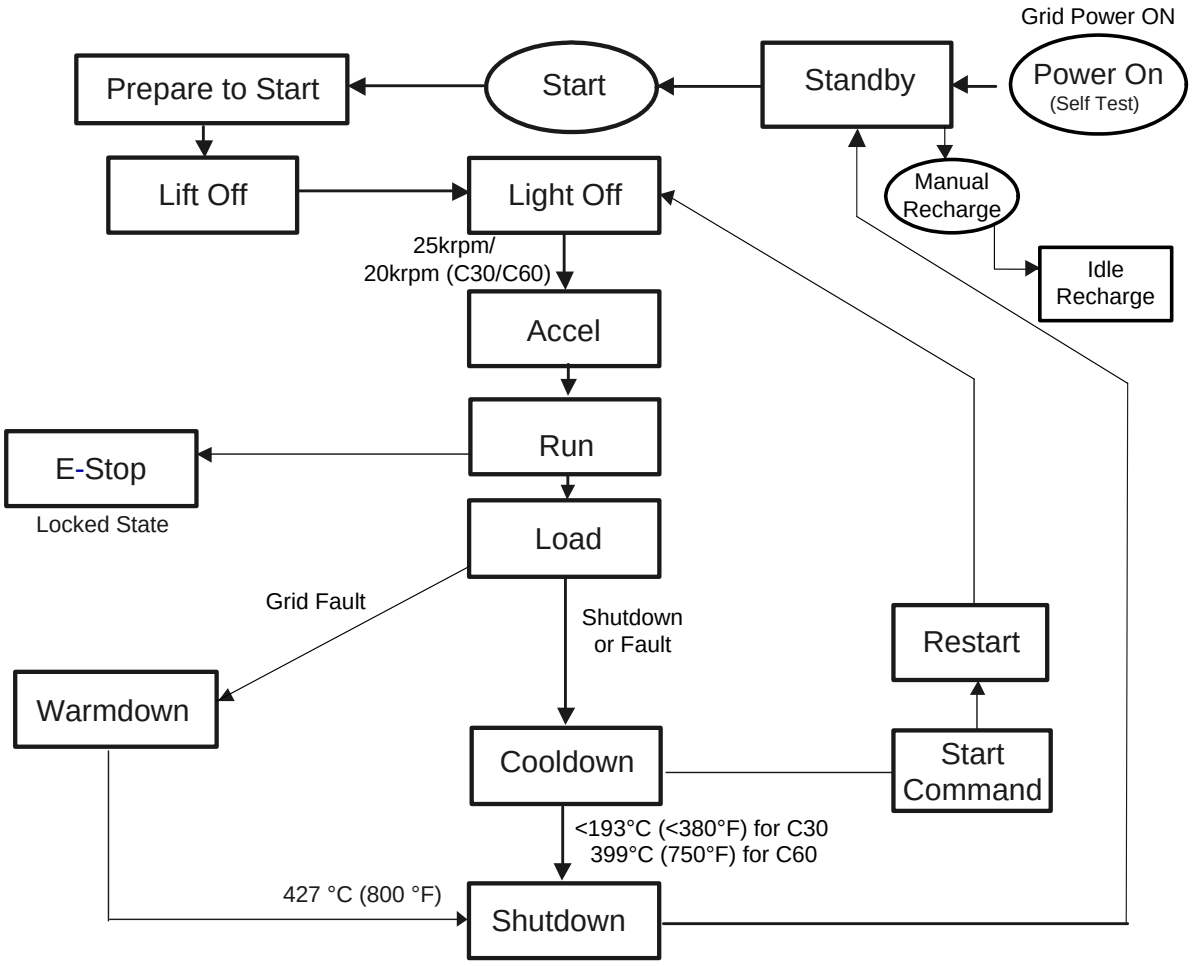


Figure 3. System State Flow Diagram

Power ON (Self Test)

As the MicroTurbine is powered up, the following events occur:

- The utility breaker is closed, bringing power to the Controller
- Voltage is applied to the DC Bus through the Precharge board to approximately 670 Vdc (for 480V grid)
- Read and verify personality module (PM) data
- Software compatibility is verified to ensure the right software is installed for components
- Communication with the display panel and fuel devices is locked

Stand By

The state is characterized by the utility providing power to the MicroTurbine controller, while the MicroTurbine is in an idle state waiting for a Start command.

Prepare to Start

When a Start command is issued, the software transitions to the "Prepare to Start" state. This state is characterized by the following events:

- Turn on power controller fans
- Verify utility voltage
- Close output contactor bringing DC bus voltage to 760V
- Check that communication with the fuel device has been established
- (Liquid fuel only) Liquid fuel drain opens if TET < 149° C (300° F) to remove any fuel remaining in the recuperator from prior start attempts (Liquid fuel vaporizes > 300° F)

Lift Off

This state is characterized by engine rotation - voltage and current are applied to the permanent magnet generator to provide torque for rotating the engine components.

- Generator speeds up to 25 krpm (Model C30)
- Generator speeds up to 20 krpm (Model C60/C65)

Light Off

This state is characterized by the air-fuel mixture combustion.

The following events occur:

- (Liquid fuel only) Liquid fuel drain closes for operation
- Turn on Intra A power - controls fuel shut off device and solenoids which allow fuel flow into the system. Turn on Intra C power for RFC
- Turn fuel devices on
  - Includes air-assist device for liquid fuel systems
- Power is applied to the igniter through the spark exciter solenoid
- Enable fuel shutoff and injector solenoids
- Increase fuel flow with the igniter on until an increase in TET is detected. If this increase is not detected within 30 seconds, a 6006 "Fail to Light" fault is declared.

Accel

This state is characterized by ramped generator acceleration.

The following events occur:

- Turn off spark exciter solenoid/igniter
- Ramp speed/fuel flow to maintain combustion while raising generator speed to 49 krpm

Run

This state is characterized by the system delivering minimum power while the output contactor remains closed. The turbine will operate with fuel at 49 krpm for up to one minute to warm up engine components and remain in the Run state after the warm up is complete.

The following events occur:

- Operating with fuel at 49 krpm (Model C60/C65) for up to one minute to warm up engine components
- Minimal power may be exported based on differences in ambient temperature

Load

This state is characterized by engine acceleration to meet the user power demand. Control remains in the Load state until a fault occurs or a stop command is given.

The following events occur:

- Speed varies from 49 to 96 krpm to meet power demand
  - TET nominally 671 °C (1240° F) at 49 krpm to 593 °C (1100° F) at 85 krpm and above for the Model C30
  - TET nominally 635 °C (1175° F) for full speed range for the Model C60/C65
  - Temperatures may be reduced with decreasing ambient temperature
- Number of injectors used increases with power output
- If Stand Alone equipped, performs battery equalization charge every 15-30 days
  - Initiated only in allowed times programmed by user. Once charging starts, it cannot be stopped - this process is invisible to the user.

Cooldown

As the MicroTurbine shuts down, the system enters a cooldown period. A Start command can be provided during this period either manually or via the auto restart feature. Restart allows higher availability after faults by returning to the Load state without a complete shutdown of the engine rotating components.

The following events occur:

- Electrical fuel shutoff is closed so it is not producing any more fuel
- Power production is reduced (heat in recuperator may result in power output while engine decelerates)
- A purge of a liquid fuel system with air assist occurs to clear fuel out of the fuel lines through the injectors
- The fuel solenoids are closed
- Speed is reduced to Cooldown speed
  - Cooldown at 45 krpm for Model C30
  - Cooldown at 50 krpm for Model C60/C65
- Cooldown speed provides airflow over engine components until TET reaches:
  - 193 °C (380° F) for Model C30
  - 399 °C (750° F) for Model C60/C65

- A timed shutdown occurs if a 3004 "BOTH TET" fault occurs:
  - 10 minutes for the C30
  - 5 minutes for the C60/C65

Shutdown

Upon completion of Cooldown, the software transitions to the Shutdown state.

The following events occur:

- Stop generator
- Turn off fans
- Open output contactor

Warmdown

This state is characterized by a system fault or abnormal user shutdown. In the case of a Grid or Load fault, control will transition to Warmdown. With a load fault, the output contactor is opened immediately and therefore utility power is not available to support Cooldown. The dump valve is pulsed to control speed, allowing airflow for cooling, while preventing engine over speed conditions. As heat is removed from the recuperator, the engine will coast to a stop.

The following events occur:

- Voltage Transient is sensed
- Power production is ceased
  - Output contactor is opened
- The fuel solenoids are closed
  - Intra A power is off
  - Intra C power is off (RFC)
- Energy produced while the engine decelerates is dissipated to the brake resistor
- Enter Fault state at 427° C (800° F) TET

E-Stop Shutdown

This state is characterized by a user-initiated effort to halt MicroTurbine operation immediately and IS NOT RECOMMENDED. E-Stop shutdowns provide no cooling to the engine components and the engine coasts to a stop, causing wear to the bearings. The number of emergency stops is tracked by the software and may void the warranty should engine failure occur. The following events occur:

- Power export ceases immediately
  - Output contactor opens
- Gas fuel solenoid valve is closed
  - Intra A power is Off
  - Intra C power is Off (RFC)
- Dump valve opens to remove air flow from engine - preventing engine over speed conditions
- Rotor coasts to a stop

Configuring the Dispatch Modes

NOTE	Changing any default dispatch mode requires a password. The user password is "**87712370"**. Viewing existing dispatch mode settings do not require password entry.

Dispatch modes take advantage of the special capabilities and features designed into the Grid Connect mode for providing power. The MicroTurbine can be configured to operate in Manual or External mode. Manual mode is the default. External mode allows the MicroTurbine to be operated via electrical contacts.

Manual Dispatch (Default)

The Manual dispatch is the default mode for a newly shipped MicroTurbine. Manual dispatch mode allows the MicroTurbine to be commanded ON/OFF manually and then commanded to an output power level.

This requested output power can be retained in non-volatile EEPROM memory for an indefinite period and applied at the next MicroTurbine start-up if the value is entered through the display panel or through the RS-232 command PWRDST.

- CRMS: Select: *Settings* > *User Connection Bay Settings*, and set the Start Input slider to User Start Priority (Mode 0). To set the power demand value for the current session only, navigate to the main menu, and enter the value in the "kW Demand" field. To enter a power demand value to be retained on next start-up, select *Settings* > *Control Settings,* and enter a value in the "Stored Power Demand" field.
- Display panel:
  - Select the Manual Dispatch mode as follows: *System Data* > *System Configuration* > *Start Input*, and select the "User" option.

System Configuration	Parameter Description	Parameter Value	Default
Start Input <option>	Allows user the option to select local/remote mode of control.	User Remote (UCB) GC User/SA Remote SA User/GC Remote	User

  - Select the power level: *Grid Connect* > *Set Demand*, and enter the desired power (kW).

Grid Connect Menu	Parameter Description	Parameter Value	Default
Set Demand <kW>	Configures the electric utility grid to deliver a specific value of power.	0.0 – 2000000.0 kW	0.0

External Switch

The External Switch mode allows an external signal to control the START/STOP status of the MicroTurbine at the commanded output power level for Grid Connect. Figures 1 and 2 show the location of the UCB contact terminals required to enable the external switch.

Software may be configured to recognize the external switch as follows:

- CRMS: Select: *Settings* > *User Connection Bay Settings*, and set the Start Input slider to Remote Start Priority (Mode 1).
- Display panel: Navigate as follows - *System Data* > *System Configuration* > *Start Input*, and select the "Remote (UCB)" option.

Load Management Mode

Load Management mode allows the user to optimize MicroTurbine power generation efficiency. The two modes available are Time of Use and Load Following. To enable Load Management dispatch mode:

- CRMS: Select: *Settings* > *Load Management Settings*, then adjust the Load Management slider from Normal to either Load Following or Time of Use.
- Display panel: Navigate as follows: *System Data* > *System Configuration* > *Load Management*, and select either the Time of Use or Load Following option.

System Configuration	Parameter Description	Parameter Value	Default
Load Management <select>	Selects method of optimizing MicroTurbine power generation efficiency.	1 - Normal 2 - Time of Use 3 - Load Management	Normal

Normal

In Normal mode, the MicroTurbine utilizes electric utility grid power in excess of constant MicroTurbine base power to meet the customer power demand, referred to as Base Loading. Figure 4 illustrates the normal MicroTurbine operating mode. In the example, the MicroTurbine supplies 30 kW base power and the electric utility grid supplies the rest of the load demand.

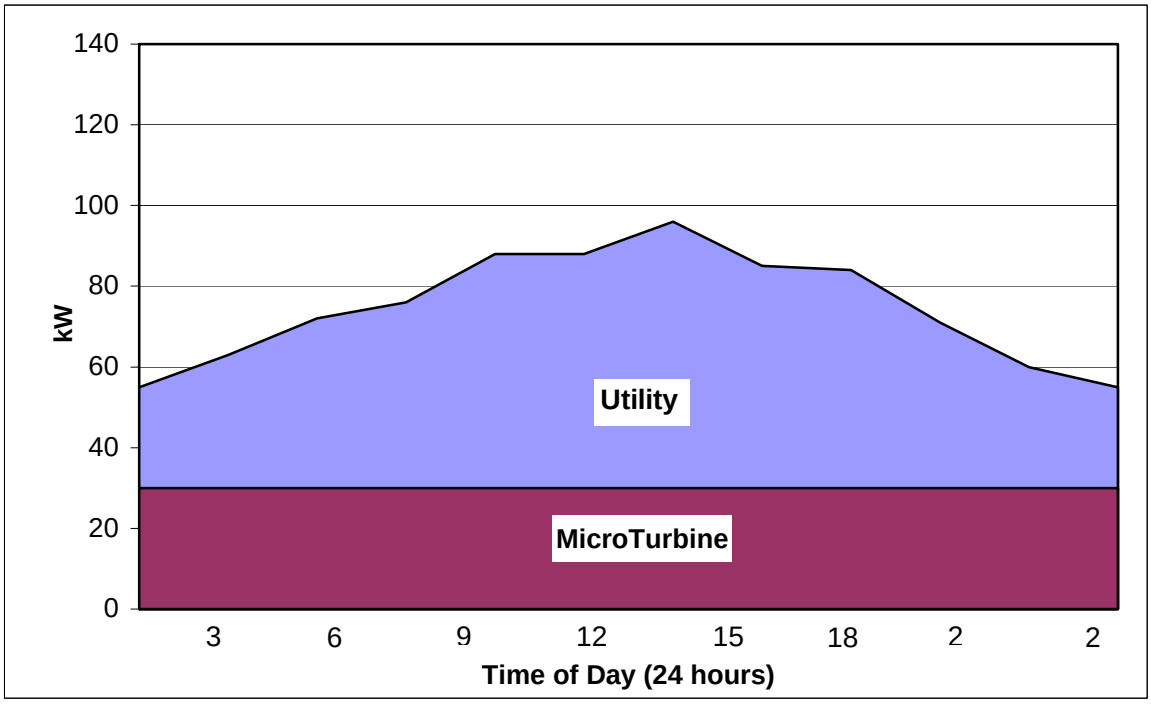


Figure 4. Normal Dispatch Mode

Time of Use

Time of Use may be used for peak shaving during periods of the day when electricity from the utility is at a premium. Time of Use mode allows the user to selectively determine start/stop commands and/or power output levels for up to 20 timed events. Events are programmed by day of week, time of day, and power demand in any order, and sorted by time to determine event order. Figure 5 illustrates how a MicroTurbine may be used in Time of Use mode.

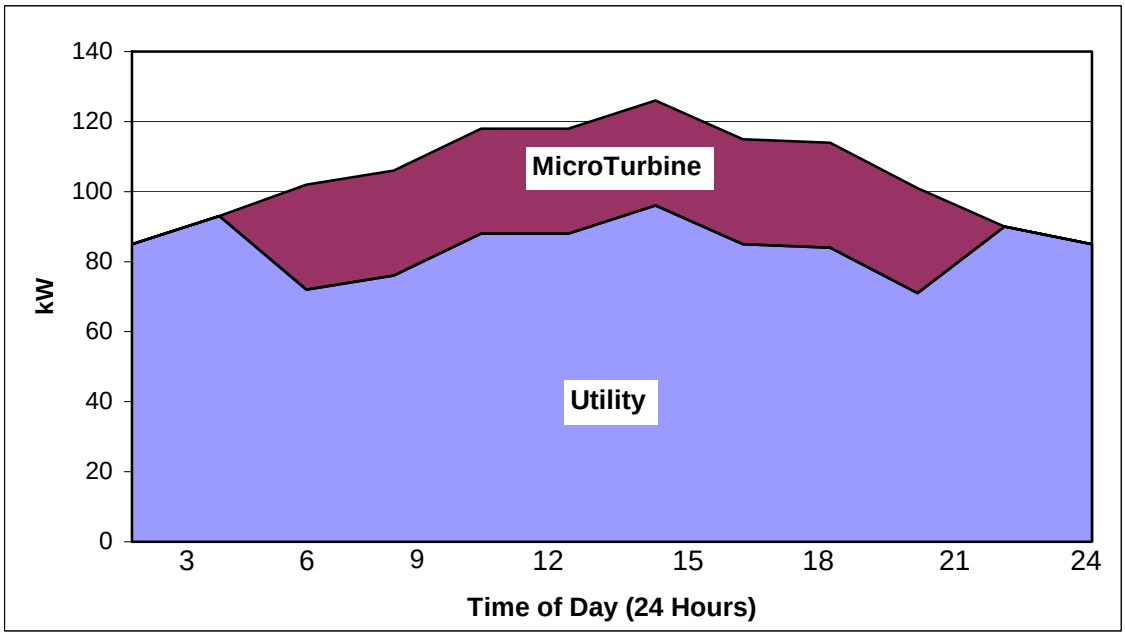


Figure 5. Time of Use Dispatch Mode

- CRMS: From the menu, select *Settings* > *Time of Use* Settings, and configure the desired turbine parameters.
- Display panel: Navigate to *Time of Use* menu and configure desired parameters as follows.

Time of Use Menu	Parameter Description	Parameter Value	Default
1/20 LMTOU Event <select>	Programs the on/off and power demand schedule for the MicroTurbine.	Event 1 to 20	1 (Enable)
Day of Week <Active/Inactive/Day>	Identifies day of week for event execution	Inactive = 0 Sunday =1, Saturday = 7	0 (Inactive)
Time <Hour/Min/Sec>	Time of day for event to execute. Format: HH:MM:SS	00:00:00 to 23:59:00	00:00:00
Command <Start/Stop>	Allows start/stop command for the MicroTurbine of an event	Stop = 0 Start = 1	0 (Stop)
Power Demand <kW>	Power output demand level for the event. Format: no decimals	0 to 2000000 kW	0

Load Following

NOTE	Load Following requires an external power meter. The power meter is not supplied with the MicroTurbine and must be connected between the MicroTurbine and the electric service entrance. See "External Power Meter Installation" section regarding meter requirements.

Load Following mode utilizes MicroTurbine power in excess of the base power supplied by the utility grid (when required by external loads), allowing the MicroTurbine to track local electrical loads, and supplying only as much power as is required. The MicroTurbine regulates the utility power flow to an adjustable maximum - the utility power setpoint. If the local demand rises above this level by an adjustable amount for a selected time period, the MicroTurbine is dispatched to supply the difference (up to its capacity). As the MicroTurbine power output varies, supplying up to 30 kW of power above the utility power setpoint (100 kW), as required by the current load demand.

Figure 6 illustrates how a MicroTurbine may be utilized in Load Following mode.

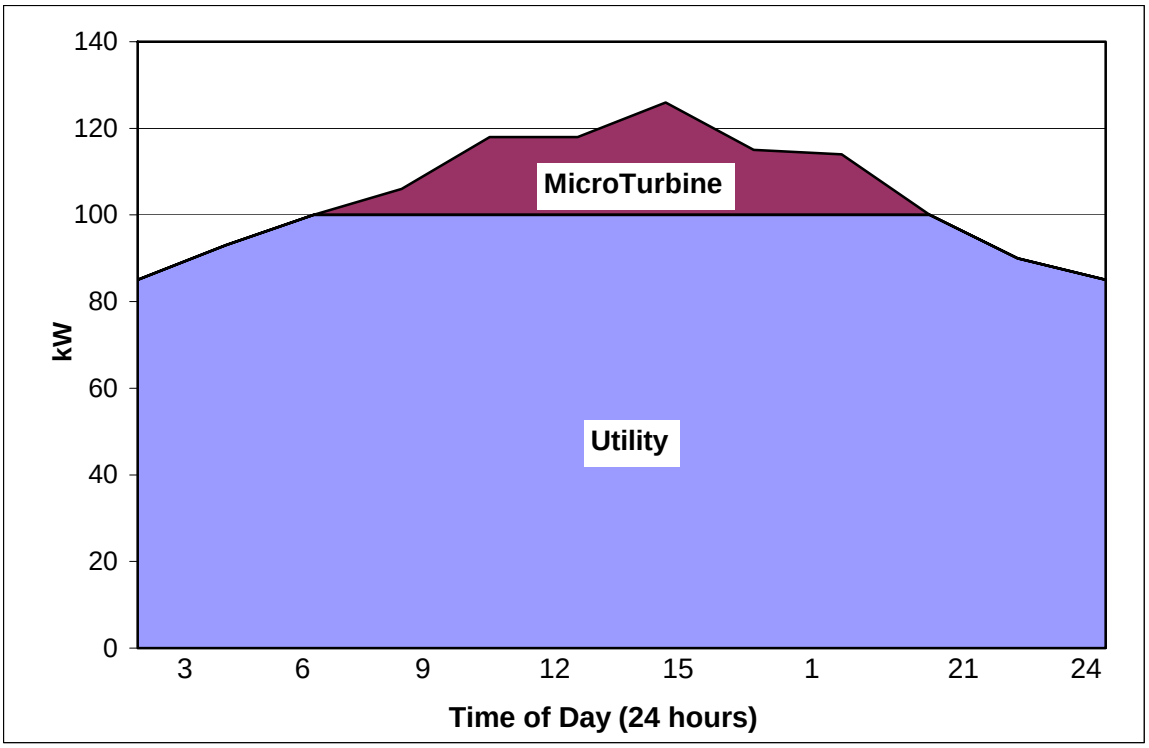


Figure 6. Load Following Dispatch Mode

The Load Following mode is used in the following situations: 1) To reduce peak demand charges (where applicable), 2) When power draw from the utility grid is limited by supply equipment capacity, or 3) If installed MicroTurbine capacity exceeds the minimum local load demand and net revenue metering is not allowed by the utility.

Parameters are as follows:

- *Reverse Power Protection* enables the system to automatically shutdown if the external power meter registers negative power flow (see *Reverse Power Flow Protection*).
- *Utility Power* indicates the allowable upper/lower utility power limits as controlled by the external power meter.
- *Response Time* shows required time before the system responds with a new output command based on power meter signals; acts as filter to smooth out transients.
- *Minimum Power Shutoff* assigns an allowable power limit below the utility setpoint (based on kW demand) that the MicroTurbine will operate before shutting down.
- *Minimum Power Startup* assigns a minimum power limit for the turbine to turn on (based on kW demand) if the system load exceeds the utility setpoint. This parameter is intended to maximize system efficiency by allowing the utility grid to continue operation instead of the MicroTurbine at lower power levels.
- *Meter Constant* specifies the number of watt-hours represented by a single pulse signal from the external power meter.

Load Following settings are configured as follows:

- CRMS: From the menu, select: *Settings* > *Load Management*, and then configure the desired parameters.
- Display panel: Navigate to the *Load Management* menu, and configure the parameters.

Load Management Menu	Parameter Description	Parameter Value	Default
Rev Pwr Protect <Disable/Enable> <seconds>	Enables the system to automatically shutdown if the power meter registers negative power flow	 Disable/Enable 0 to 120 seconds	 0 (Disable) 120
Utility Pwr <kW>	Allowable upper/lower utility power limits as controlled by the external power meter	-1000 to +1000 kW	0
Response Time <Sec>	Required time before the system responds with a new output command based on power meter signals; Interval is used to smooth out power transients	1 to 120 seconds	1
Min TPwr Shutoff <kW> <min>	Power limit below the utility setpoint (based on kW demand) that the turbine will operate before shutting down; Interval is the delay time before turbine shutdown	0 to 1000 kW 0 to 15 min	0 0
Min Pwr Startup <kW> <min>	Minimum power limit for the turbine to turn on (based on kW demand) if the system load exceeds the utility setpoint; Interval is the delay time before MicroTurbine start up. Parameter is intended to maximize efficiency by limiting turbine operation at lower power levels.	0 to 1000 kW 0 to 15 min	0
Meter Const <Wh/pulse>	Power Meter pulse scaling – usually preset at installation and not adjusted	0 to 500.00 Wh/pulse	0.00

Auto Restart

Enabling Auto Restart allows the system to automatically attempt a restart after an incident-driven shutdown. If Auto Restart is ON, the system will attempt to restart after most system shutdown modes. This feature may be enabled with any of the listed dispatch modes. Capstone recommends enabling Auto Restart to increase system availability, deliver faster power output and reduce wear on the bearings.

If the Auto Restart feature is enabled, the system stores the ON command even through a loss of Operator intervention may be required to manually restart the system if a fault condition occurs and the related protective relay interval is exceeded. The MicroTurbine must be explicitly commanded ON for automatic operation to be enabled. Enter a Restart Delay time to provide the additional time required between start attempts for any connected external devices.

- CRMS: From the menu, select: *Settings* > *Control Settings*, and set Auto Restart to ENABLE. If a time delay is required before restarting the MicroTurbine, enter the delay time in the *Auto Restart Delay – Grid Connect* field.
- Display panel:
  - Select Auto Restart mode - *System Data* > *System Configuration* >*Auto Restart*, and then select ON.

System Configuration	Parameter Description	Parameter Value	Default
Auto Restart <No/Yes>	Allows the system to restart itself after a electric utility (grid) interrupt	No Yes	No

  - Select a restart delay time - *Grid Connect* > *Restart Delay*, and enter a time period.

Grid Connect Menu	Parameter Description	Parameter Value	Default
Restart Delay <Min>	Sets the time period after restart that MicroTurbine powers up.	0 – 60 min	0

MultiPac Power

In MultiPac mode, MicroTurbines can be installed in groups of up to 20 units (100 units with the optional Capstone PowerServer) to operate as a single power generation source. The electric utility grid transmits control signals locally to the MultiPac configuration, activating as many MicroTurbines as required to meet the required power demand. Individual MicroTurbines share power and load on both a dynamic and steady state basis. Refer to the MultiPac Technical Reference (410032) for information on MultiPac configuration and operational requirements.

To configure MultiPac power requirements in Grid Connect mode:

- CRMS: From the menu, select *Settings* > *MultiPac Settings*, enter the Turbine number in the adjacent field and set the toggle to Enable.
- Display panel: Navigate as follows - *System Data* > *System Configuration* > *Turbine Number* and enter a unique turbine identifier. Then, navigate to *System Data* > *System Configuration* > *MultiPac,* and select Enable.

System Configuration	Parameter Description	Parameter Value	Default
Turbine Number <Number>	Select a unique numerical identifier for MultiPac configuration	1 – 20	1
MultiPac <Enable/Disable>	Enables or disables MultiPac configuration	0 = Disable 1 = Enable	0 (Disabled)

Fast Transfer Mode Capability

NOTE	Effective August 2005, Dual Mode system owners may incorporate a set of software changes in Model C60/C65 v4.4X+ to take advantage of improved transition speed between Stand Alone and Grid Connect modes. For more information on hardware modifications and overall retrofit requirements, refer to "DMC Modifications – Model C60/C65 Fast Transfer Functionality (440123) Work Instructions."

Integration of fast transfer functionality must be enabled through software settings in the display panel "Grid Connect" menu or by using RS-232 commands. Hardware modifications must also be performed to take advantage of fast transfer functionality.

Grid Connect Menu	Parameter Description	Parameter Value	Default	RS-232
GC Enable Mode <Auto/Manual>	Each time the system attempts to reconnect to the grid, either recovering from a grid fault condition or during a MicroTurbine restart, it will check the GC Enable Mode (Auto/Manual) setting. Auto – If GC Enable Mode is set as Auto, the system will verify the grid is in a non-fault condition for a period determined by the GC Reconnect Delay setting. Once it has been determined that the grid is in good condition, the system will attempt to restart automatically (If Auto Restart has been enabled). Manual – If the GC Enable mode is set to Manual, the system will wait for a user Start command which will make the system transfer to GC operation immediately.	0 = Auto 1= Manual	Auto	GCEMOD
GC Reconnect DLY <Min>	Defines the transition time delay for the system to check the grid reconnection condition before returning control to GC mode. This setting applies only when the GC Enable Mode is set to Auto. Enter <Time> in minutes until grid returns.	5- 30 Minutes	5 Minutes	GCRDLY

Engine Operating Mode

The Model C30 MicroTurbine can be operated in two modes, Power mode or Efficiency mode.

Efficiency mode is the factory-installed, everyday control method that applies to most customer applications. In efficiency mode, engine temperature (TET) is regulated based on engine speed to achieve efficiency at all speeds.

Power mode is an alternative, reducing TET while increasing engine speed and generator voltage (increased power output) but limiting generator current to protect internal electronics. Although power mode may produce an overall increase in power, this mode would only be used if gas efficiency were not a priority.

Capstone recommends ALWAYS keeping the MicroTurbine in efficiency mode, unless otherwise directed by Capstone Technical Support. In older Model C30 systems prior to May 2001, some users experienced a lower power output in efficiency mode due to component limitations. However, this situation has been corrected through improved rotor cooling and the incorporation of new generator inductors.

To configure engine operating mode:

- Display panel: Navigate as follows: *System Data* > *System Configuration* > *Engine Mode*, and select either Efficiency or Power.
- CRMS: From the menu, select *Settings* > *Control Settings*, position the Engine Mode toggle switch in the desired position – Efficiency or Power.

Reverse Power Flow Protection

Reverse Power Flow Protection mode prevents the MicroTurbine system from backfeeding power to the grid and can be enabled in either operating mode. If the MicroTurbine output is greater than the local load demand, the excess power generated by the MicroTurbine will flow back to the grid. Return flow to the grid is undesirable for two reasons: 1) The grid utility does not allow net metering, and requires that generating equipment cease operation if this condition exists, and 2) Reverse power flow represents an economic loss to the MicroTurbine user.

Reverse Power Flow Protection may be used independently of other grid connected dispatch modes. 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. This allows cooldown of the MicroTurbine to occur as opposed to a Grid Fault warmdown (shutdown) caused by an external disconnect.

NOTE	Some states have rigid requirements regarding proper reverse power flow to the utility during grid disturbances. In this case, the best approach is to use a proper reverse power flow detection relay to detect reverse power on any phase. The detection relay circuit should interface with one of the MicroTurbine digital fault inputs and be software configured to fault severity level 4 (warmdown). When properly setup, the output contactor on the MicroTurbine will open as soon as the relay detects a reverse power flow condition.

The Reverse Power Flow Protection dispatch mode requires installation of an external power meter connected to the MicroTurbine. 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.

- CRMS: From the menu, select *Settings* > *Load Management Settings*, toggle the Reverse Power Protection switch to ON, and then configure settings.
- Display panel: Navigate as follows*: Load Management* > *Reverse Power Protection*, enable the feature, and enter the desired time period.

Load Management	Parameter Description	Parameter Value	Default
Rev Pwr Protect <Disable/Enable> <seconds>	Enables the system to automatically shutdown if the power meter registers negative power flow for specified time	Disable/Enable 0 to 120 seconds	0 (Disabled) 120

External Power Meter Installation

The Load Following and Reverse Power Flow functions require the installation of a 3-phase power meter at a remote location from the MicroTurbine. MicroTurbine hardware and software is designed to accept signals from a pulse-output power meter. See Figures 6 and 7 for power meter connections.

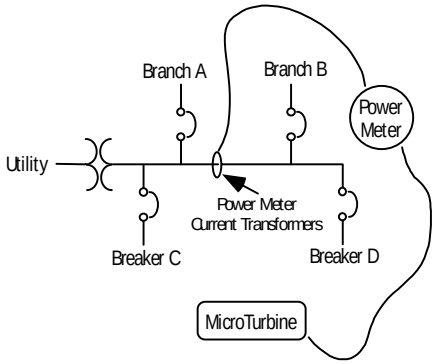
Pulse-output power meters provide a contact closure pulse indicating when a specific amount of energy has passed through the meter. The quantization of energy per pulse is either fixed or programmable depending upon the meter.

There are two sets of contact closure inputs. One set provides contact pulses for forward energy flow, and the other set provides energy for reverse energy flow:

- Power flow in the forward direction (toward the loads) is measured as +PWR.
- Power flow in the reverse direction is measured as –PWR.

The external power meter should be placed in a location to produce the demand signal. Loads on the load side of the power meter current transformer location will produce demand signals, load on the utility side will not.

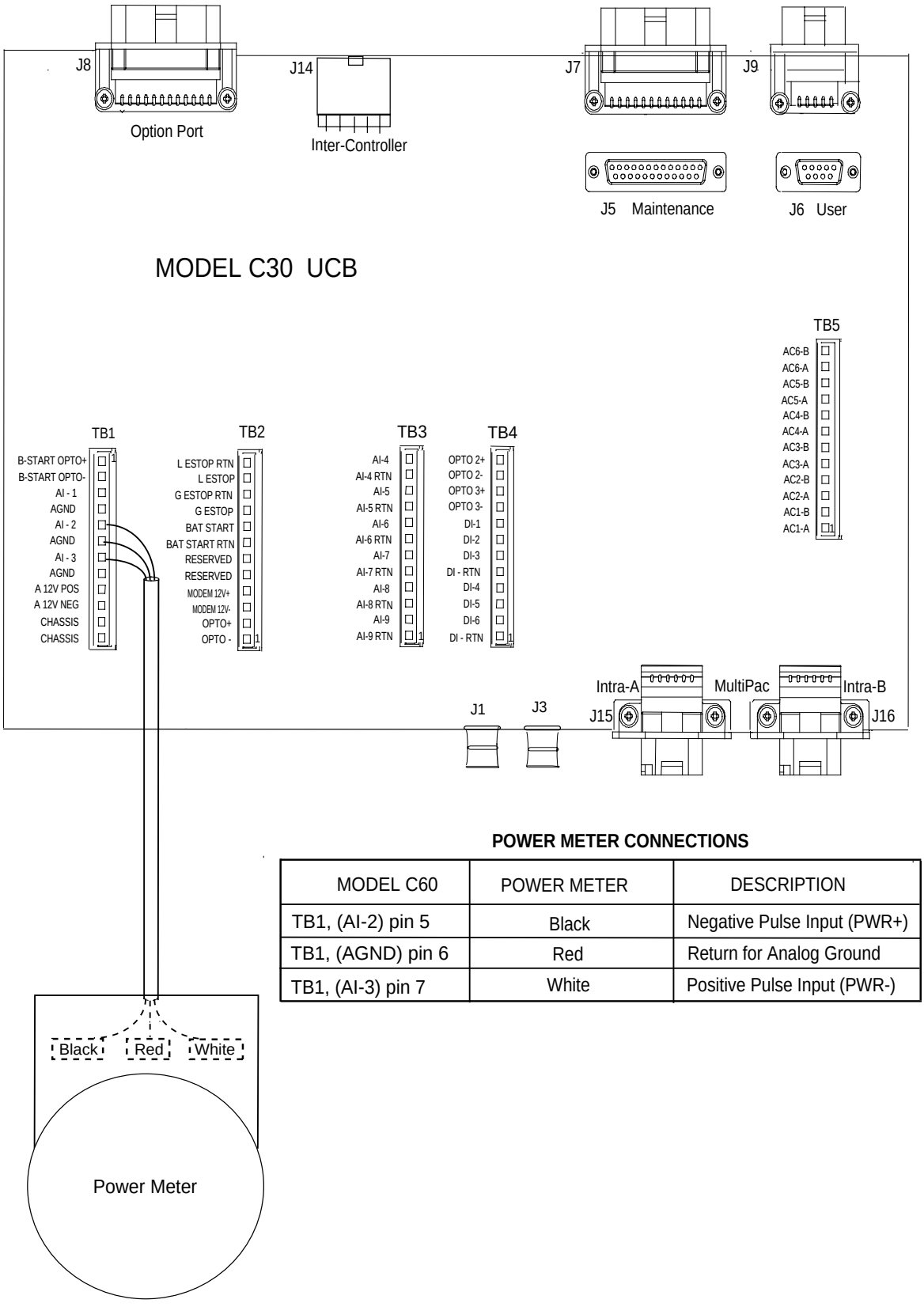
The demand on the MicroTurbine will be calculated as the difference between the Utility Power setting entered during this setup and the actual load measured by the power meter.



Typical Power Meter Interconnection

For example, in the illustration above, loads on Branches B and D only will determine the MicroTurbine power output demand. Branch A or C loads have no effect.

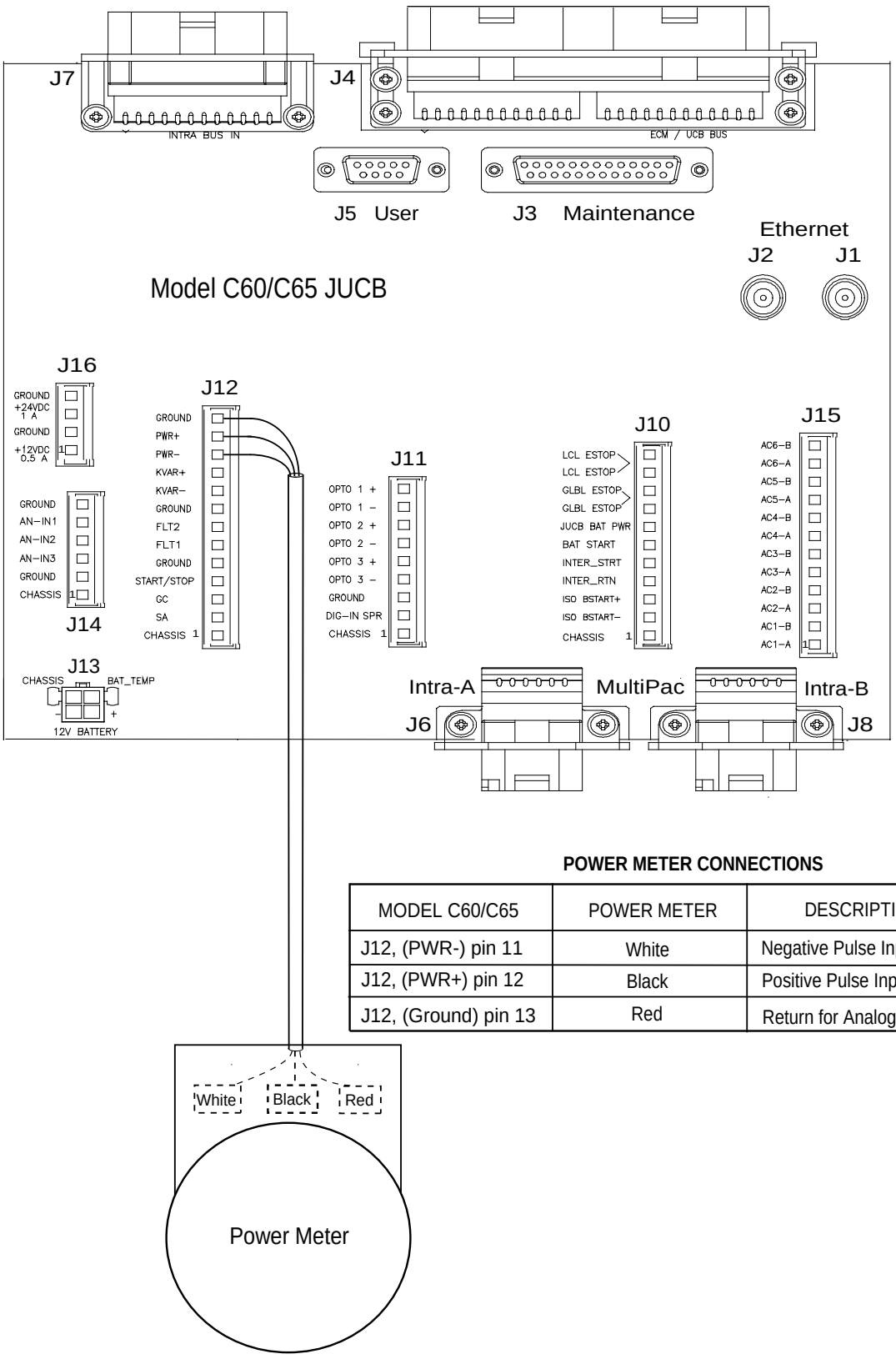
The Micro-Turbine may be connected at either Breaker location, C or D (or an entirely difference circuit). Power output demand will still be determined by the flow through the power meter current transformers.



POWER METER CONNECTIONS

MODEL C60	POWER METER	DESCRIPTION
TB1, (AI-2) pin 5	Black	Negative Pulse Input (PWR+)
TB1, (AGND) pin 6	Red	Return for Analog Ground
TB1, (AI-3) pin 7	White	Positive Pulse Input (PWR-)

Figure 7. Power Meter Connections (Model C30)



POWER METER CONNECTIONS

MODEL C60/C65	POWER METER	DESCRIPTION
J12, (PWR-) pin 11	White	Negative Pulse Input (PWR-)
J12, (PWR+) pin 12	Black	Positive Pulse Input (PWR+)
J12, (Ground) pin 13	Red	Return for Analog Ground

Figure 8. Power Meter Connections (Model C60/C65)

Programming the Meter Scaling Constant

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 transmitters employed between the power meter and the power wiring. Thus, the overall calibration factor seen by the MicroTurbine is as follows:

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

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 2000A to 5A current transformer would have a CRT of 2000/5 = 400

PTR = Potential transformer ratio (voltage at power meter / voltage at bus).

DIV = Any other division ratio applicable to the power meter;
Example: A 480V to 120V potential transformer would have a PTR of 480/120 = 4

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

Ke is the scaling constant that should be entered into the display controller. The power meter internal calibration factor, current transformer ratio and voltage transmitter ratio must be such that the scaling constant falls in the range 0 – 500.000 W-h/pulse.

Protective Relay Settings

The MicroTurbine software supports undervoltage, overvoltage, and frequency protection limits in accordance with UL 1741. Refer to the Protective Relay Technical Reference (410033) for details.

Capstone Technical Information

If questions arise regarding Grid Connect operation for your Capstone MicroTurbine, please contact Capstone Turbine Technical Support for assistance and information.

Capstone Technical Support
Toll Free Telephone: (877) 282-8966
Service Telephone: (818) 407-3600 • Fax: (818) 734-1080
E-mail: service@capstoneturbine.com

Capstone Technical Support (Japan)
Service Telephone: (818) 407-3700 • Fax: (818) 734-1080
E-mail: servicejapan@capstoneturbine.com

Capstone Turbine Corporation
21211 Nordhoff Street • Chatsworth, CA 91311 • USA
Telephone: (818) 734-5300 • Fax: (818) 734-5320
Website: www.microturbine.com