



Application Guide - Model C60 Dual Mode – Fast Transfer

Introduction

Capstone MicroTurbines™ are prime power generators, producing high quality, commercial-grade electric power in an energy dense, small footprint. Capstone MicroTurbines' clean exhaust and co-generation capabilities allow installation close to a load with complete control at the customer's fingertips. These characteristics allow for low installed cost, quick start-up and low maintenance costs.

MicroTurbines can be used to produce power with a Utility grid (Grid Connect), to work as a Stand Alone generator, or a combination of both – referred to by Capstone as “Dual Mode” functionality. Due to their design versatility, they can be applied in a variety of applications. They are currently used to provide continuous power to hotels, grocery stores, oil-field processing equipment, schools and office buildings, as well as highly-reliable off-grid power to data centers, telecom equipment and protected manufacturing processes.

This Application Guide explains the performance and switching logic between Grid Connect and Stand Alone modes of operation for the Capstone C60 and C60 ICHP Dual Mode MicroTurbines with firmware version 4.50 or higher, which includes the ability for “Fast Transfer” between Grid Connect and Stand Alone operating modes. This document also describes operation of the Dual Mode Controller in combination with the C60 to achieve Fast Transfer. Refer to the Capstone Dual Mode Controller Technical Reference 410039 (Rev D or higher), and DMC Field Re-work Instruction 440123, which documents the latest construction required for Fast Transfer.

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Summary

The C60 Dual Mode version MicroTurbines with firmware version 4.50 and higher are able to transition from Grid Connect to Stand Alone, and from Stand Alone to Grid Connect operation, with only a few seconds of time delay between these operating modes. Capstone calls this capability “Fast Transfer”, which can be extremely beneficial for protected loads that value high availability of power. This application guide explains how Fast Transfer functions, how it works with the Capstone Dual Mode Controller, and provides general application guidance. Refer to other Capstone Product Specifications and Technical References listed at the end of the application guide for more details.

In summary, the C60 Dual Mode MicroTurbines in combination with Capstone’s Dual Mode Controller, are able to provide less than 10 seconds transition time between Grid Connect operation and Stand Alone power in the case of a Utility outage, and to reconnect the protected loads back to the Utility grid within 2 seconds after normal conditions have been reestablished. The sections below provide the details on how the C60 MicroTurbine and Dual Mode Controller function to accomplish this high level of load protection.

UL 1741 Requirements for Utility Interconnection

C60 MicroTurbines are UL listed to 2200 and 1741, and meet the harmonics requirements of IEEE 519. They are also pre-certified for Utility interconnection by many local jurisdictions to simplify connecting to the Utility grid, such as in California and New York. These local certifications often rely on the UL 1741 listing, which defines how power inverters must react to disturbances on the Utility grid. Before describing the Fast Transfer capability of the C60 Dual Mode version MicroTurbines, it may be useful to review how the C60 achieves the UL 1741 listing and how it operates under typical Utility grid disturbances.

Figure 1 shows a one-line schematic of a C60 Grid Connect version MicroTurbine connected to the Utility grid. In this example, short circuit and overload protection is provided by the circuit breaker CB1 between the MicroTurbine and the Utility grid. The protective relay functionality required by UL 1741 is integral to the C60 firmware, and includes voltage, frequency, and anti-islanding functions. Following is a short description of how the basic C60 Grid Connect version (not a Dual Mode version) reacts to a Utility disturbance.

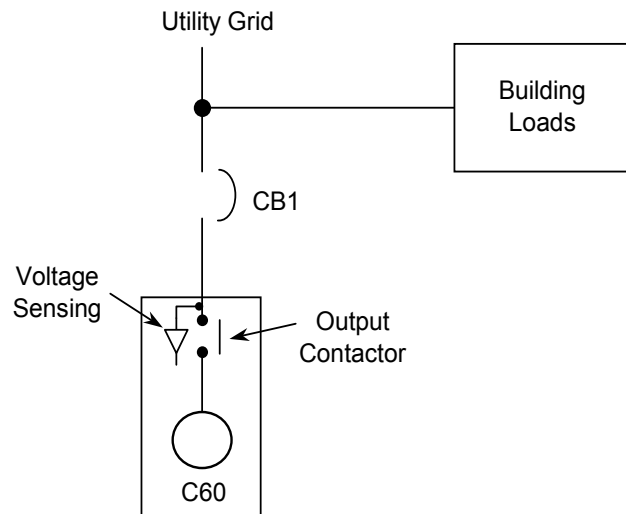


Figure 1. One-line Diagram of C60 Connected to Utility Grid

In normal Grid Connect operation, the output contactor in the C60 is closed and the MicroTurbine is generating power. The MicroTurbine's generated power flows out to the remainder of the distribution circuit, and is consumed by the building loads. Normally, power is not exported to the Utility grid. In the event of a disturbance on the Utility grid, voltage and current sensing integral to the C60 MicroTurbine will cause the internal contactor to open and the MicroTurbine to go through a shutdown procedure. The response time will, of course, depend on the type and severity of the disturbance and the protective relay settings in the MicroTurbine. Refer to Technical Reference 410033 for details on these protective relay functions and setpoints.

With the MicroTurbine output contactor open, Utility voltage can still be sensed by the C60 circuitry. When Utility voltage returns, the MicroTurbine senses it and an internal "reconnect" timer is started. UL 1741 requires that the MicroTurbine not reconnect to the grid for at least 5 minutes after the Utility voltage and frequency have been restored to the normal operating ranges. The Capstone C60 provides for user adjustment of this internal reconnect timer from 5 to 30 minutes. Some local interconnection regulations may also require manual intervention before reconnecting any power source to the Utility grid. To address this case, the C60 MicroTurbine firmware also provides for a manual command on the display or through the RS232 communications port. When this manual Utility reconnect control function is enabled, the MicroTurbine will reconnect to the grid as soon as a manual command has been sent to permit reconnection. Capstone's CRMS remote monitoring software provides a user interface for issuing this manual "permission to reconnect" command. A communications command can also be transmitted through the RS232 port in the case that a PLC or other digital control equipment is used. The C60 MicroTurbine display also provides for this manual reconnection using the "Start" command.

When the conditions have been met to allow reconnection to the Utility grid, the MicroTurbine will automatically close its output contactor, use the Utility grid to start the MicroTurbine, and begin generating power again in Grid Connect mode. Figure 2 shows a timeline of this sequence for a typical Utility fault, followed by an outage.

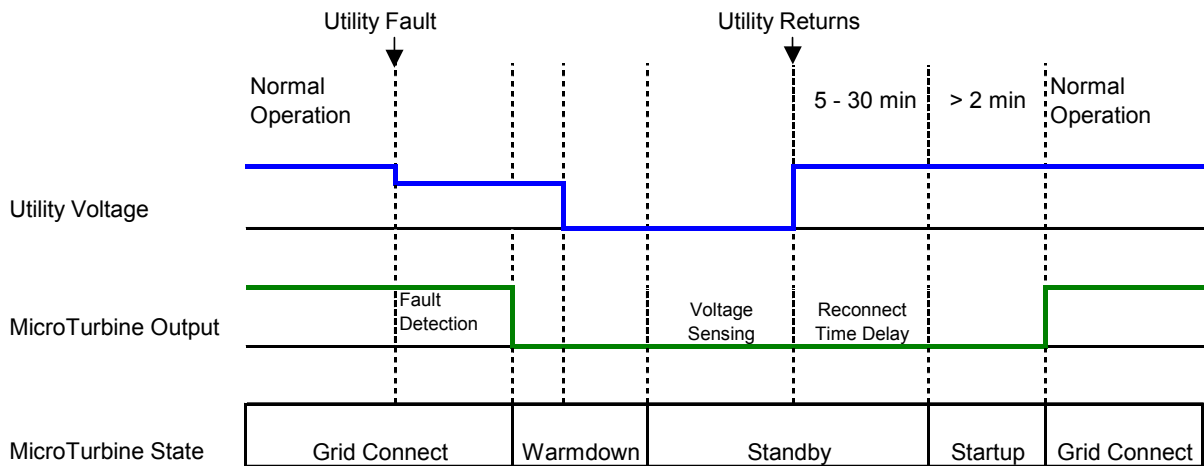


Figure 2. Timeline of Typical Utility Fault

Dual Mode Functionality

When the Capstone C60 MicroTurbine includes the Dual Mode feature, it is capable of providing power either connected to a Utility grid (Grid Connect mode) or without presence of a Utility voltage (Stand Alone mode). Since the operating characteristics between these two modes are different, the MicroTurbine must be told which mode to be in. The User Connection Bay (UCB) terminal J12 has two hardware interfaces to enable Grid Connect (GA Enable - pin 2) or Stand Alone operation (SA Enable - pin 3). If the user wants to operate in only one of these modes, a hardware jumper must be connected from pin 2 or 3 to ground to enable the desired mode, and the desired mode must be selected under “Power Connect” on the MicroTurbine display or CRMS software. Alternatively, the MicroTurbine can be set up for automatic transition between these two modes by wiring control logic between the two mode-enable inputs and ground. The MicroTurbine must then be set for Dual Mode operation in the “Power Connect” menu. Fast Transfer only applies when the MicroTurbine is set to Dual Mode operation, and the mode-enable inputs are properly wired and controlled. Note that “Active” is defined for these mode-enable inputs as being connected to ground (or “Low”). Additionally, the Start/Stop input to the MicroTurbine (UCB terminal J12, pin 4) is used to control the desired mode of operation, as described below, where “Start” means pin 4 is connected to ground (or “Low”).

Grid Connect to Stand Alone Mode

When the GC Enable and SA Enable inputs are toggled, and the Start/Stop input is set to “Start”, the MicroTurbine passes through the following transition states, as shown in Figure 3:

1. Output contactor is opened within about 50 milliseconds to stop export of power from the C60 MicroTurbine,
2. The MicroTurbine generator continues to produce power, which is available to recharge the battery pack,
3. The MicroTurbine firmware transfers to the new output mode,
4. The output contactor closes, making the MicroTurbine power available to the system in the Stand Alone operating mode.

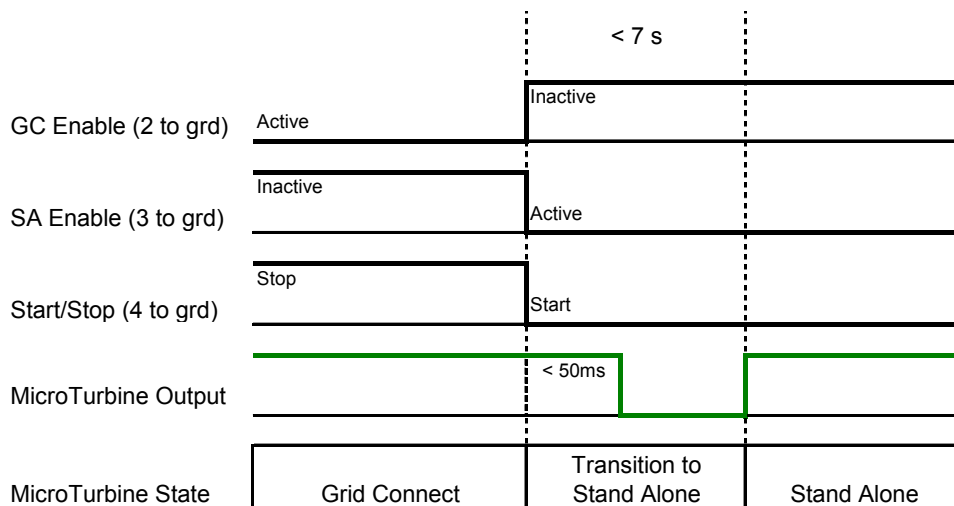


Figure 3. Fast Transfer from Grid Connect to Stand Alone

The transition time between Grid Connect and Stand Alone modes is less than seven seconds, but will be delayed if the sensed voltage at the MicroTurbine output is maintained above 50V peak (for example by rotating machines with high inertial loads).

The transfer from Grid Connect to Stand Alone operation is extremely fast, and may not necessarily provide the desired total system functionality. For example, if an external control system toggles the input signals as noted in Figure 3, but the associated isolation device has not completely disconnected from the Utility grid within the transition time of the MicroTurbine, a fault condition may exist that could damage equipment. For this reason, the operation of the input signals should assure that conditions are right for the Fast Transfer operation.

Capstone’s Fast Transfer firmware allows an intentional delay time between Grid Connect and Stand Alone operation by using the SA Enable and Start/Stop inputs as shown in Figure 4. For the MicroTurbine to discontinue operation in Grid Connect mode, only the GC Enable input needs to become inactive. For transition to Stand Alone operation, both the SA Enable and the Start/Stop inputs must become active (the example shows both operating at the same time, but it is possible to have either one lead the other). Until both SA Enable and Start/Stop become active, the MicroTurbine will operate in “Hot Standby” mode for up to two hours, or until the batteries are completely recharged, whichever is longer. In this Hot Standby mode, the engine is on (flame is lit) and the output contactor is open. Power from the MicroTurbine is used to recharge the batteries, as needed, but no power is exported. Note that this “Hot Standby” mode is termed the “Stand Alone – Recharge” state in Technical Reference 410028. When the SA Enable and Start/Stop inputs become active, the MicroTurbine enters the transition state and will begin exporting power in Stand Alone mode within seven seconds. Note that if a valid control input is not received before the MicroTurbine completes its Hot Standby timeout, the MicroTurbine will shut down and remain in normal Standby until valid control inputs tell it to restart in Grid Connect or Stand Alone mode.

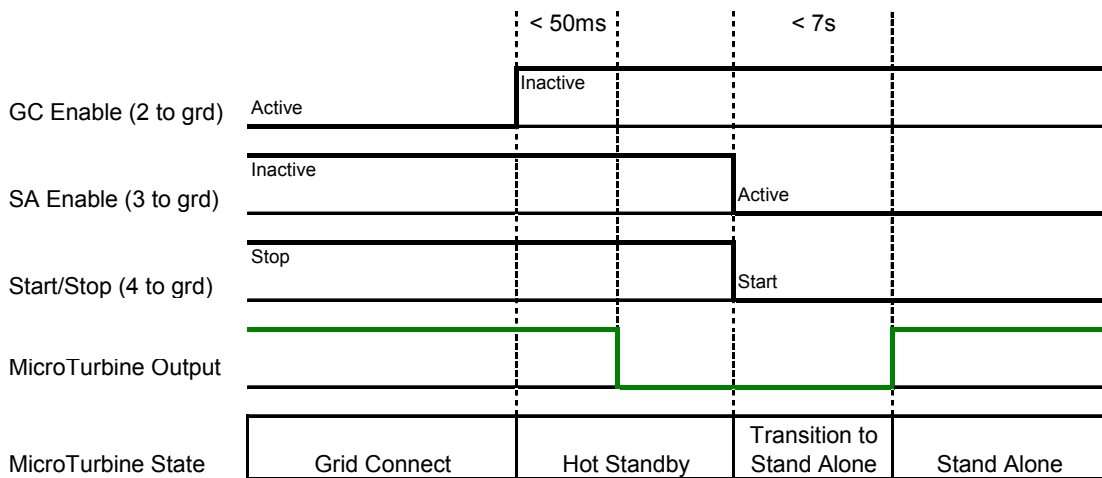


Figure 4. Grid Connect to Stand Alone with Intentional Delay

The above scenarios explain how an external system can use inputs to the MicroTurbine to force transition from Grid Connect to Stand Alone operation with or without intentional delay. However, the MicroTurbine itself includes built in protective relay functions that may operate before any external control system has responded. This is, in fact, the more probable scenario, and is Capstone’s recommended operating scheme. By letting the MicroTurbine

respond directly to a Utility fault, the protected loads may actually have more continuity of power if they are not automatically transferred to Stand Alone mode.

Figure 5 shows operation of the MicroTurbine from Grid Connect to Stand Alone, where the MicroTurbine initiates the transfer. For simplicity of explanation, the example shows a drop in Utility voltage as the fault. Of course, it could be other fault conditions that cause this operation, such as over or under frequency, over voltage, or anti-islanding protection.

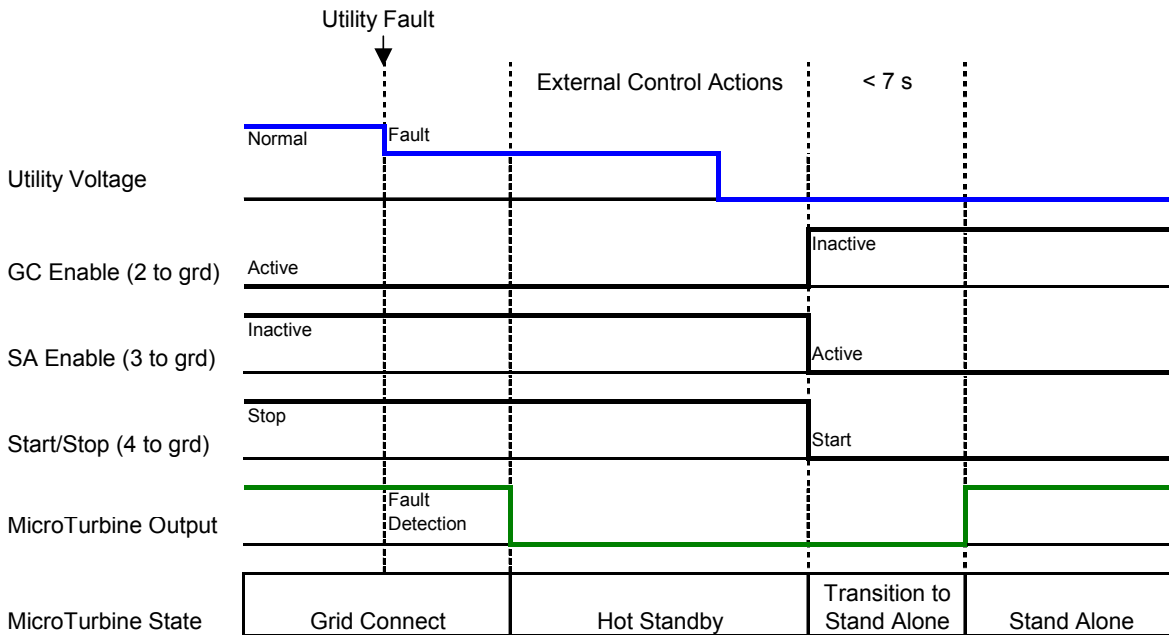


Figure 5. Grid Connect to Stand Alone Initiated by MicroTurbine

In this case, the MicroTurbine reacts to the fault first, with the external control system toggling the GC Enable, SA Enable, and Start/Stop inputs thereafter. The time delay is controlled by the external system, however there are some conditions that must be considered for this control action. While the GC Enable is active, the MicroTurbine will automatically start its internal reconnect sequence and prepare to reconnect to the Utility grid. During this process, the MicroTurbine will look for presence of stable Utility voltage at its terminals (just as described in the Grid Connect only operation above). As soon as Utility voltage is sensed, the MicroTurbine will start its reconnect timer. If GC Enable is not deactivated prior to reaching the set reconnect time delay (or activation of any manual reconnect controls), the MicroTurbine will automatically resynchronize with and reconnect to the Utility grid. If there is no Utility grid present, the MicroTurbine will continue in Hot Standby mode for up to two hours, waiting for the presence of Utility voltage prior to starting its reconnect time delay sequence. Note that if normal Utility voltage does not return, or a valid control input is not received, before the MicroTurbine completes its Hot Standby timeout, the MicroTurbine will shut down and remain in normal Standby until valid control inputs tell it to restart in Grid Connect or Stand Alone mode.

Note that there are two possible scenarios in the transition out of Grid Connect mode:

1. An external control system forces the transition from Grid Connect to Stand Alone, with or without the MicroTurbine responding directly to a Utility fault condition, or

2. An external control system does not force a transition from Grid Connect to Stand Alone, but the MicroTurbine responds directly to a Utility fault, and then automatically enters its reconnect sequence to transition back to Grid Connect operation.

Scenario 1 represents “Fast Transfer” between the two modes of operation. In this case, any protected loads will see an interruption in power of several seconds going to Stand Alone operation (depending on the control system), followed by another interruption of several seconds when the system transfers back to Grid Connect mode. Scenario 2 represents a Utility disturbance only. The protected load will see the transient that caused the MicroTurbine to disconnect, and may not see any power interruption at all.

Stand Alone to Grid Connect Mode

The transfer back from Stand Alone to Grid Connect operation includes a one minute fixed time delay after the SA Enable signal becomes inactive, followed by the standard reconnect sequence used for any transfer to Grid Connect operation. As shown in Figure 6, the MicroTurbine continues in Stand Alone operation for one minute after the SA Enable signal goes inactive, then automatically stops power output and goes into Hot Standby mode. As an interlock control signal, one of the output relays on UCB terminal J15 can be programmed to indicate when the MicroTurbine is supplying power to the load in Stand Alone mode (“SA Load” in Figure 6). The opening of the selected SA Load output relay terminals A to B can initiate an external logic sequence that reconnects the MicroTurbine and protected loads to the Utility grid, activates the GC Enable input to the MicroTurbine, and switches the Start/Stop input to Stop. This will cause the Utility voltage to be sensed at the MicroTurbine output terminals, and the MicroTurbine will now begin its reconnect time delay sequence, resynchronize, and output power in Grid Connect mode if the Utility voltage remains within the protective relay setting limits for the reconnect time delay.

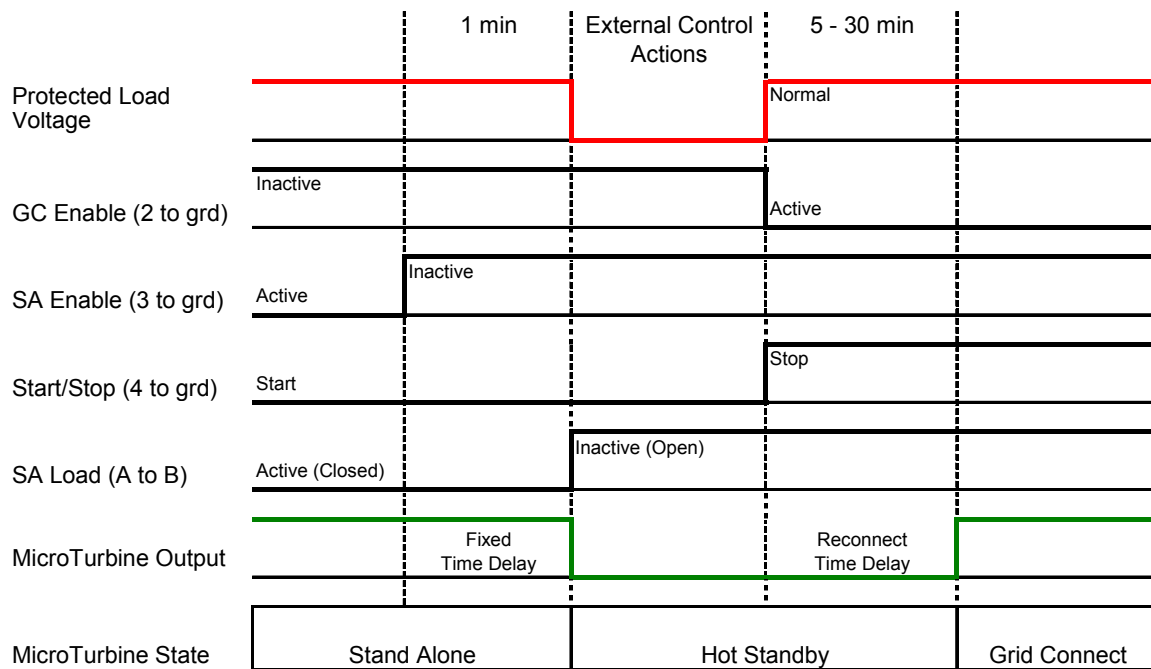


Figure 6. Fast Transfer from Stand Alone to Grid Connect

Note that if the Utility voltage experiences disturbances outside the protective relay limits during the reconnect time delay, the MicroTurbine will wait until sensed voltage is back within limits and then restart the reconnect sequence. Also note that the MicroTurbine may not continue in Hot Standby for more than two hours, and will shut down if it is not able to either transition to Grid Connect mode or if it is not commanded to go back to Stand Alone operation.

Also note that Capstone has included a second timer that is initiated when the SA Enable signal goes inactive, in order to prevent repeated cycling between Stand Alone and Hot Standby modes. If the MicroTurbine is commanded to transition to Hot Standby, and subsequently is commanded to return to Stand Alone, this second timer delays transition back to Hot Standby for ten minutes after the initial SA Enable signal went inactive.

External Controller Concerns

Since control of the MicroTurbine is now being set by external signals, it is important that the logic and sequence of operations be correct to avoid misapplication.

CAUTION: Causing the Grid Connect and Stand Alone enable inputs to be connected at the same time will cause automatic shutdown of the MicroTurbine and faults to be logged. To avoid this, make sure that the control logic to the mode-enable inputs does not allow simultaneous activation of Grid Connect and Stand Alone enable signals.

CAUTION: Commanding the MicroTurbine to operate in an incorrect mode will also cause it to automatically shut down and log the appropriate fault history. For example, the MicroTurbine will not provide voltage output to support a Stand Alone load if it is commanded to operate in Grid Connect mode. To avoid this, make sure the control logic is enabling the correct mode of operation.

CAUTION: Commanding a MicroTurbine to reconnect to the Utility grid may violate Utility interconnection regulations that require a manual reconnect procedure. To avoid this, any external control logic must be commanded to operate in accordance with local Utility interconnection regulations.

WARNING: Externally connecting a MicroTurbine operating in Stand Alone mode to an energized Utility grid may cause damage to loads that are being powered by the MicroTurbine if they are not reconnected in phase with the Utility source. Other equipment may also be damaged as a result, including the distribution system and even the MicroTurbine itself. To avoid this, make sure that power connection is not made to a Utility source when the MicroTurbine is operating in Stand Alone mode.

Capstone has developed an external accessory that properly addresses the application issues noted above – the Dual Mode Controller (or DMC). The section below describes how this DMC operates to command the MicroTurbine modes and isolate protected loads from the Utility grid.

Dual Mode Controller Functionality

Capstone offers a Dual Mode Controller (DMC) accessory that provides the external control and isolation functions to take advantage of the MicroTurbine's Fast Transfer functionality described above. Figure 7 shows a simple one-line diagram of the DMC with Utility grid, C60 MicroTurbine, and protected load. The DMC includes a motor-operated isolation switch M1, an undervoltage relay (UVR) that senses the Utility grid voltage, and control logic to operate M1 and send and receive signals from the C60 MicroTurbine. This application guide will focus on an overview of the automatic operation between Grid Connect and Stand Alone

modes. Note that the C60 MicroTurbine provides 24Vdc power to the DMC, which will not be discussed in this Application Guide. Technical Reference 410039 (Rev D or higher) provides additional details on the operation, construction, components, and interconnection wiring of the Dual Mode Controller. Also refer to DMC Field Re-Work Instruction 440123 to ensure that your Dual Mode Controller is properly set up for Fast Transfer operation.

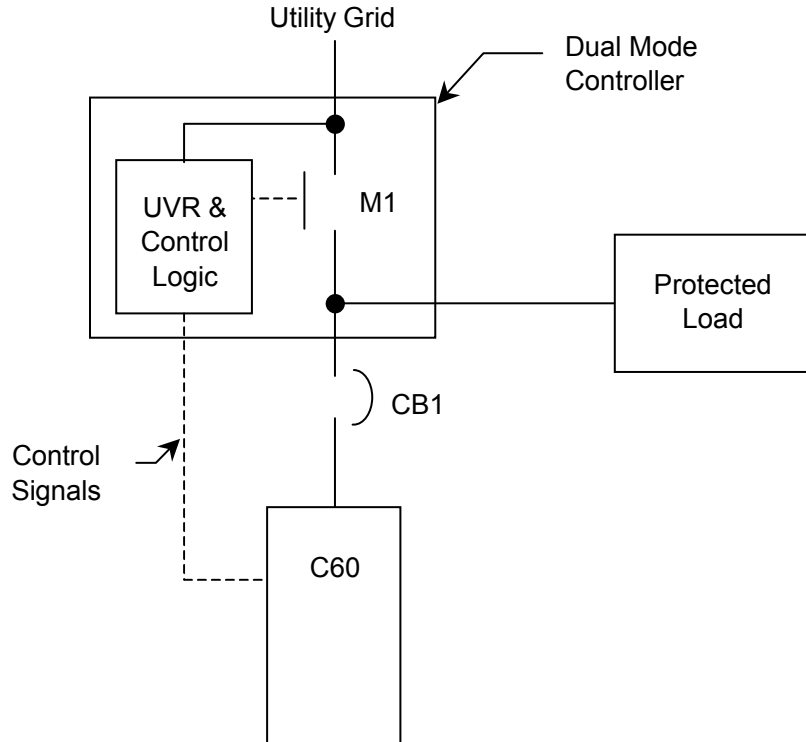


Figure 7. One-line Diagram of Typical Dual Mode Application

The control signals of interest for the Fast Transfer functionality are summarized in Table 1, as described above and repeated here for reference. Refer to Capstone Dual Mode Controller technical reference 410039 for proper setup procedures for these input/output signals.

Control Signal	MicroTurbine Input or Output	DMC Terminal #	Function
GC Enable	Input	2	Active for MicroTurbine to be in GC mode
SA Enable	Input	3	Active for MicroTurbine to enter SA mode
Start/Stop	Input	4	“Start” to Operate in SA mode
SA Load	Output Relay	9 & 10	Active (closed) when MicroTurbine in SA mode

Table 1. Fast Transfer Control Signals

Normal operation is when the Utility grid is providing stable electrical power, isolation switch M1 is closed, and the C60 MicroTurbine is providing power in Grid Connect mode. Figure 8

provides a schematic of the control logic used by the DMC to toggle the GC Enable, SA Enable, and Start/Stop signals. When the Utility grid experiences an undervoltage disturbance, the UVR in the Dual Mode Controller closes output relay contact RL1 in Figure 8. The auxiliary contacts M1-A3 in the motor operated isolation switch are normally open and contact M1-A4 normally closed, so the SA Enable and GC Enable signals are not yet toggled. Not shown in Figure 8 is the circuit that also uses an output command from the UVR to trip the motor operated isolation switch M1 open within about 2 seconds. When M1 opens, auxiliary contacts M1-A3 and M1-A4 toggle so that M1-A3 is now closed and M1-A4 is open (as shown in Figure 8). If the manually operated DMC switch contacts S1B and S2A are also closed, then SA Enable is activated and GC Enable is deactivated. The Start/Stop signal is also activated. This will cause the MicroTurbine to transition from Grid Connect mode to Stand Alone mode, as shown in Figure 9. Note that the use of the auxiliary contacts in the isolation switch M1 assures that the MicroTurbine will not be commanded to the Stand Alone mode unless it is isolated from the Utility grid. The complete transition from initial Utility voltage fault to Stand Alone will typically take less than 10 seconds, depending on the severity of the fault, protective relay delay settings in the MicroTurbine and the time delay in the DMC's UVR control circuit.

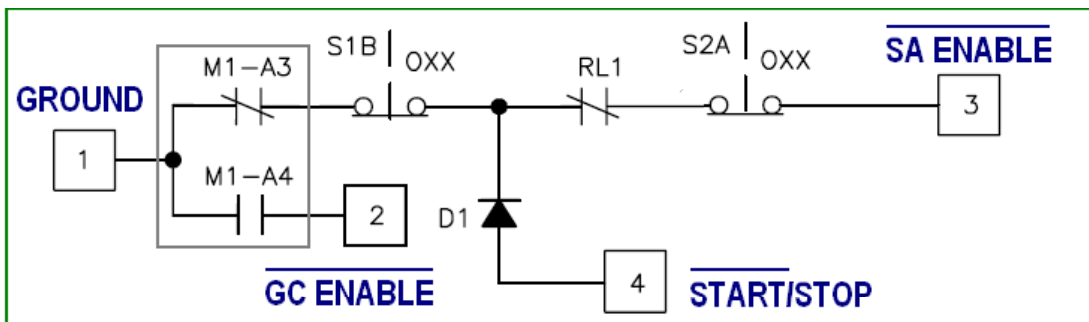


Figure 8. Control Circuit to Toggle GC and SA Enable Signals

Once the Utility voltage has returned to normal, the UVR will open contact RL1 in Figure 8. This will inactivate the SA Enable input to the MicroTurbine, as shown in Figure 9. After a fixed one-minute delay, the MicroTurbine will automatically transition to Hot Standby mode, and the SA Load output signal will go inactive. The DMC uses the SA Load inactive signal to allow the isolation switch M1 to close. Once M1 closes, the Start/Stop signal is opened by auxiliary switch contact M1-A3 causing it to become inactive, and the GC Enable signal is activated through aux switch M1-A4 (reference Figure 8). These inputs cause the MicroTurbine to begin the reconnect sequence to Grid Connect mode while the Utility grid powers the protected load. Figure 9 shows the timeline for this sequence.

Note that the total time the protected load is without normal voltage is typically less than 10 seconds after the initial Utility fault, and less than 2 seconds when the DMC transfers back to Utility Grid Connection (M1 closes).

Utility faults can occur for many reasons, resulting in a variety of transient voltage conditions. The most frequent faults are sags of relatively short duration due to short circuits on the distribution network. Depending on the impedance of the short circuit and its distance from the MicroTurbine, the resulting voltage sags are often less than 1 second, and quickly return to normal voltage when reclosing devices isolate the faulted feeder. For this reason, Capstone has designed the DMC control logic and coordinated the DMC UVR with the

MicroTurbine's internal protective relay so that the DMC only opens for more severe faults. Figure 10 shows how the DMC's UVR and the MicroTurbine's undervoltage settings are coordinated so that the MicroTurbine will be the first to respond. This means that there will be some situations where a fault is just a temporary voltage sag that causes the MicroTurbine to automatically disconnect, but does not persist long enough to cause the DMC to open the isolation switch M1. In this case, the protected load will only see the Utility voltage sag, and no interruption (and no Fast Transfer) will occur. Figure 11 shows a timeline of this scenario.

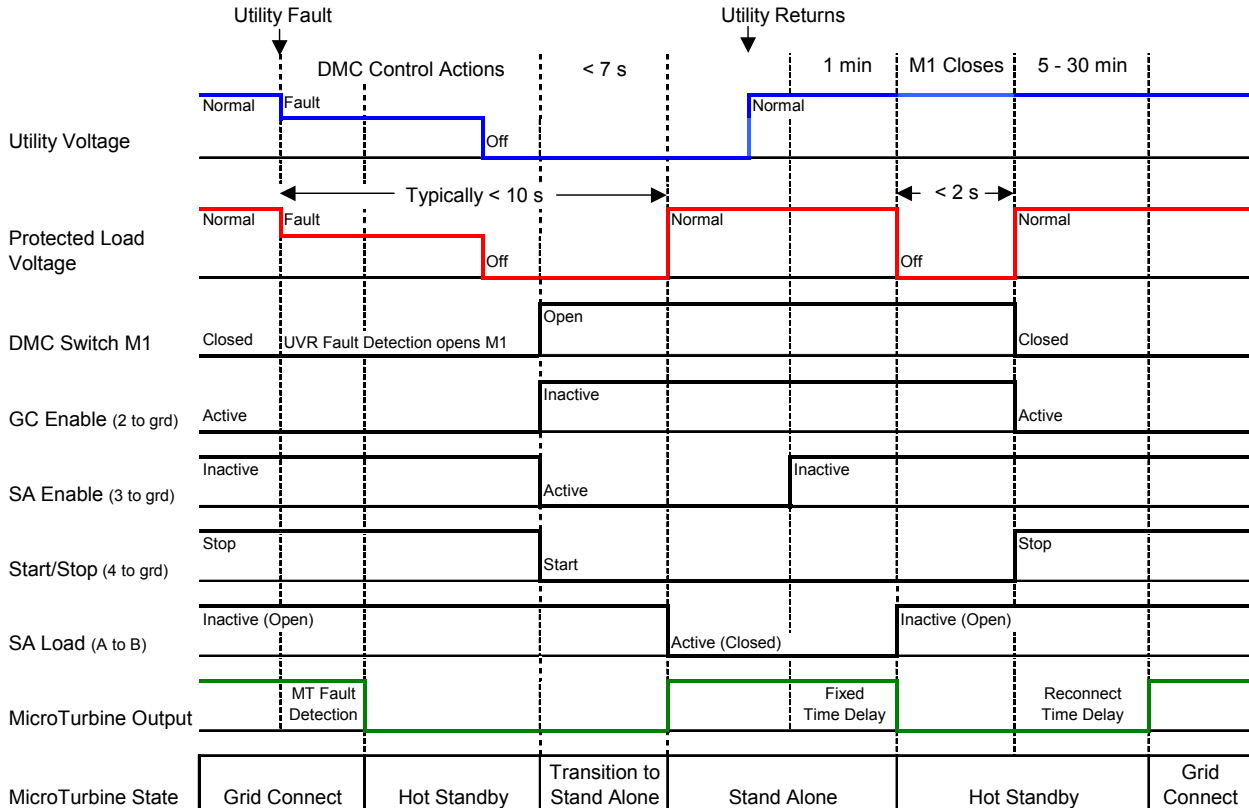


Figure 9. Fast Transfer with DMC - GC to SA to GC

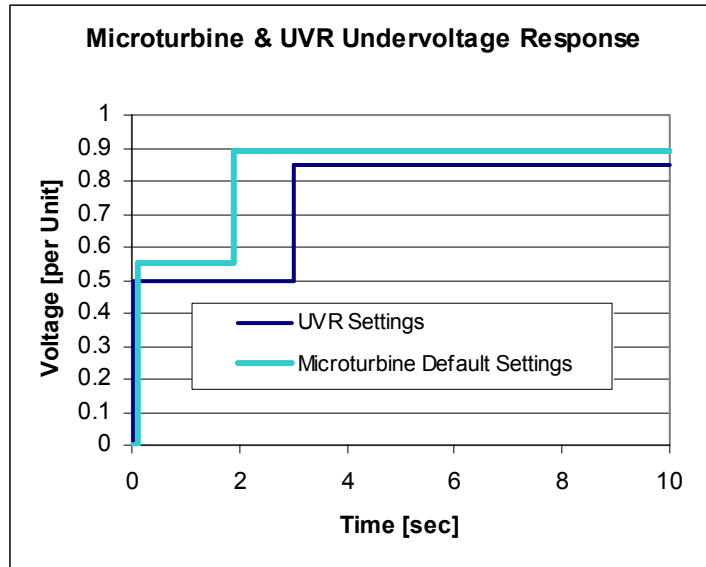


Figure 10. MicroTurbine and UVR Coordination

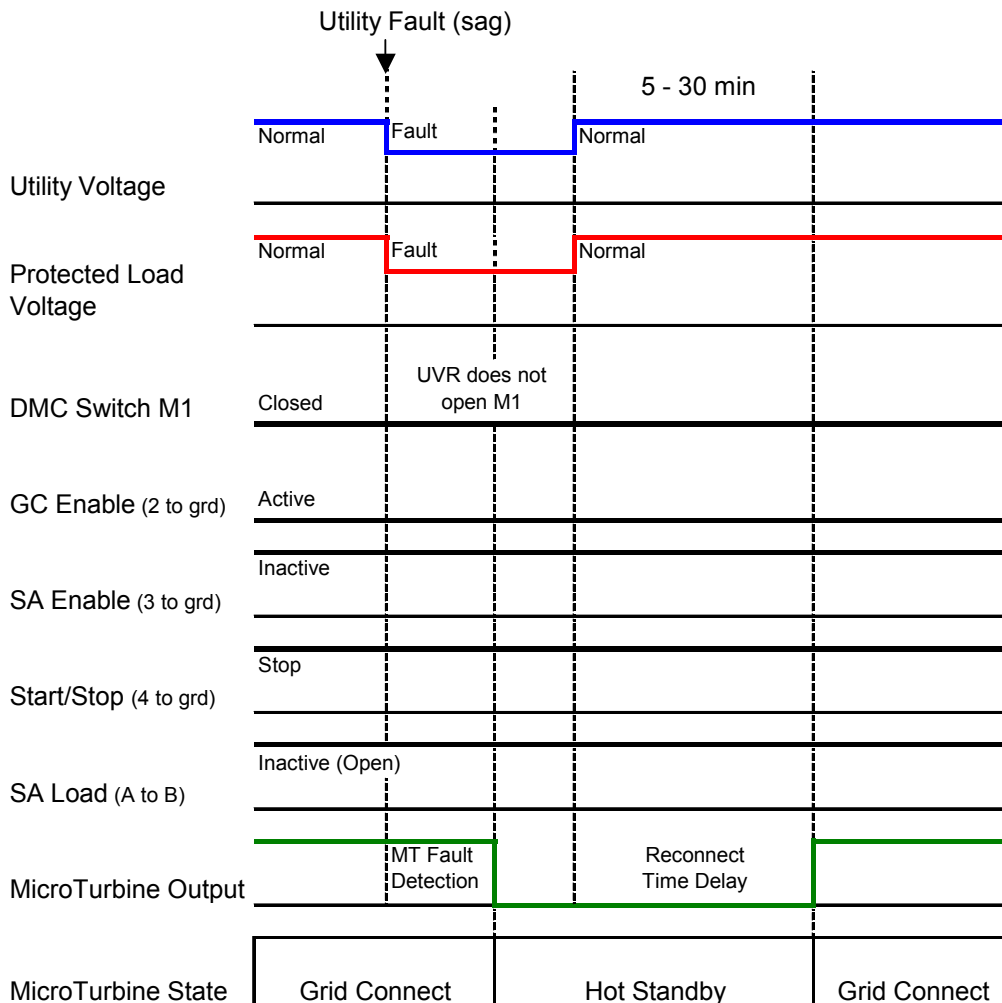


Figure 11. Fast Transfer with DMC - GC to Hot Standby to GC

MultiPac Operation with Fast Transfer

The descriptions of operation above show a single C60 or C60 ICHP MicroTurbine. When connecting several C60's in a MultiPac, the control wiring goes to the master unit, which in turn coordinates operation of the slave units. It is recommended that a second MicroTurbine be wired in parallel with the master so that it can be manually programmed to act as the master when the master unit is taken out of service. Note that Fast Transfer cannot be used with the Capstone Power Server, and control signals must be wired into a MicroTurbine master.

Since the master MicroTurbine must receive the input signals, take the appropriate actions, and then communicate to the slave units, the transition time to Stand Alone mode for a MultiPac may take slightly longer than the transition times indicated in the preceding figures, depending on the number of MicroTurbines in the MultiPac, but will still typically transition in less than 10 seconds.

Refer to Capstone MultiPac Operation Technical Reference 410032 for additional details.

C60 ICHP Operation with Fast Transfer

The C60 ICHP can be programmed to operate in several heat recovery modes. If set to Electric Priority (with thermal tracking) or Thermal Bypass, there will be no change in the operating mode when switching between Grid Connect and Stand Alone modes of operation. If the C60 ICHP is set for Thermal Priority for Grid Connect operation, it will automatically switch to Electric Priority (with thermal tracking) when operating in Stand Alone or Hot Standby modes, and switch back to Thermal Priority when operating in Grid Connect mode.

Refer to Capstone C60 Integrated CHP Technical Reference 410043 and Application Guide 480007 for additional details about the CHP modes of operation.

External Protective Relay Operation with Fast Transfer

An external protective relay may be required in some applications to meet local Utility interconnection requirements, or to provide additional protective functionality. For example, reverse power protection may be required to prevent inadvertent export under certain situations. For these requirements, the external protective relay should simply trip a circuit protective device that is located between the Utility grid and the Dual Mode Controller. The C60 MicroTurbine and DMC will then respond to the loss of voltage at the input terminals to the DMC, as shown in Figure 9. When Utility voltage is returned to normal, the circuit protective device can be re-closed, which will reestablish Utility voltage at the DMC input terminals and cause the DMC's UVR to close isolation switch M1. Note that the C60 MicroTurbine will then monitor the Utility voltage for the preset reconnect time prior to reconnecting in Grid Connect mode, in accordance with UL 1741 requirements.

See Capstone Dual Mode Controller Technical Reference 410033 for additional details.

Related Documentation

The following table lists applicable Capstone documentation.

Document No.	Document Title
400000	Capstone MicroTurbine Users Manual
410005	Capstone Model C60 Performance Technical Reference
410028	Capstone Stand Alone Operation Technical Reference
410032	Capstone MultiPac Operation Technical Reference
410033	Capstone Protective Relay Functions Technical Reference
410039	Capstone Dual Mode Controller Technical Reference & Drawings
410043	Capstone Model C60 Integrated CHP System Technical Reference
440123	Capstone DMC Field Re-Work Instruction
460000	Capstone MicroTurbine Product Specification
480007	Capstone Model C60 Integrated CHP Application Guide

Capstone Technical Information

If questions arise regarding application of Fast Transfer functionality for your Capstone C60 MicroTurbine system, please contact Capstone Turbine Application Engineering for assistance and information.

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For questions regarding operation of your Capstone C60 MicroTurbine, contact Capstone Technical Support for assistance.

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