
Capstone

Capstone MicroTurbine
Model C200 User's Manual

Capstone Turbine Corporation
21211 Nordhoff Street, Chatsworth, California 91311 USA

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It includes a description of the major components and how they interact, detailed product performance, and basic application guidance. It is intended to be used by a variety of audiences, and provides references to additional information which may be needed to answer more detailed questions. Within this document, you will find hyperlinks that will direct you to related topics in sections you are referencing. Clicking these links will move the document to that section. Below are a few examples of how this technical reference may be useful to selected audiences Architects, Engineers, and other Equipment Specifiers Capstone microturbines are gas turbines with a variety of unique features compared with traditional forms of electric generation. This technical reference provides an overview of how the Capstone C200 operates, along with detailed performance information. This information is intended to assist project specifiers and designers to properly select the right Capstone C200 microturbine for a given application, and then complete a system design that includes the selected microturbines. Other documents that may be relevant for this purpose are C200 Product Specification 460045 This document summarizes the key performance characteristics of the C200 microturbine, and is the basis for Capstone s standard warranty. The Product Specification information has precedence in the case of any conflict with this technical reference. Fuel Requirements Technical Reference 410002 The fuel requirements document provides detailed information about fuel characteristics required for proper operation of any Capstone microturbine. Emissions Technical Reference 410065 The emissions for all Capstone distributed generation products are summarized in this technical reference to address local air permitting requirements Rev C June 2009 11 Capstone microturbines are gas turbines with a variety of unique features compared with traditional forms of electric generation.http://adamhu.com/javier/dyndns-manual-login.xml

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This document provides information that will properly set expectations as to performance and behavior of the C200 microturbine. Other documents that may be relevant for this purpose are C200 User s Manual 400008 The C200 User s Manual provides explanations of how to interact with the C200 microturbine including details of the local user display, as well as general maintenance guidance and simple troubleshooting. CRMS Technical Reference User s Edition 410013 The user edition Capstone Remote Monitoring Software CRMS provides more detailed interaction with the C200 than the local display alone. The CRMS User s Edition explains how to operate this optional software. C200 Product Specification 460045 This document summarizes the key performance characteristics of the C200 microturbine, and is the basis for Capstone s standard warranty. Capstone Installers and Service Personnel The C200 Technical Reference is intended to be a hub from which installers and service technicians can find all relevant technical details regarding the troubleshooting, installation, sizing, and interconnection of the equipment. CRMS Technical Reference Maintenance Edition 410014 The service edition of the Capstone Remote Monitoring Software CRMS provides more detailed interaction with the C200 than the local display alone. The CRMS Maintenance Edition explains how to operate this service software. C200 Troubleshooting Guide 430070 This document provides detailed descriptions of troubleshooting codes and suggested actions to resolve problems Rev C June 2009 12 A turbinedriven highspeed generator is coupled with digital power electronics to produce high quality electrical power. The Capstone microturbine is a versatile power generation system suitable for a wide range of applications. Capstones proprietary design allows users to optimize energy costs while operating in parallel with an electric utility grid.http://dgjst.com/upfile/dyndns-manual-espa-ol.xml


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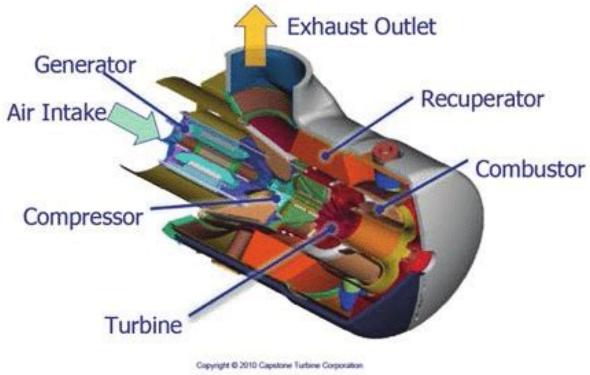
The Alternating Current AC electrical power output from the microturbine can be paralleled with an electric utility grid or with another generation source. The microturbine can act as a Stand Alone generator for standby, backup, or remote offgrid power. Multiple systems can be combined and controlled as a single larger power source, called a MultiPac. The microturbine can efficiently use a wide range of approved hydrocarbonbased gaseous fuels. The microturbine produces dry, oxygenrich exhaust with ultralow emissions. Utilizing both the generated electric power and the exhaust heat can provide even greater energy cost savings. Key Mechanical Components The key mechanical components that make up the Capstone microturbine are shown in Figure 21. Figure 21. Typical Capstone C200 Turbogenerator Construction Rev C June 2009 21 Patented air bearings eliminate the need for oil or other liquid lubricants. Aircooled design of the entire system turbine and controller eliminates the need for liquid coolants. The engine has only one moving part no gears, belts, or turbinedriven accessories. Advanced combustion control eliminates the need for ceramics or for other costly materials or for catalytic combustion, and provides ultralow emissions. The integral annular recuperator heat exchanger doubles electrical efficiency. Digital control technology facilitates advanced control and monitoring, and diagnostic capabilities, both onboard and remotely. The microturbine utilizes air foil bearings air bearings for high reliability, low maintenance, and safe operation. This allows fewer parts and the absence of any liquid lubrication to support the rotating group. When the microturbine is in operation, air film separates the shaft from the bearings and protects them from wear. Emissions The Capstone microturbine is designed to produce very clean emissions. The exhaust is clean and oxygen rich approximately 18% O 2 with very low levels of air pollutants.

Like all fuel combustion technology, the microturbine produces emissions like nitrogen dioxide and carbon monoxide from the fuel combustion process. The microturbine has ultra low nitrogen dioxide NO 2 and carbon monoxide CO emission levels. Refer to the Capstone Emissions Technical Reference 410065 for details. Enclosure The microturbine standard enclosure is designed for indoor and outdoor use, and conforms to the National Electrical Manufacturers Association NEMA 3R requirements Rev C June 2009 22 This option allows operation either with or without connection to an electric grid termed Grid Connect or Stand Alone operation respectively. This Dual Mode option includes two large battery packs used for unassisted start and for transient electrical load management. The battery packs are leadacid type and completely sealed. When operating in Stand Alone mode, the system can power connected loads at userselected voltage and frequency setpoints. It can power remote facilities such as construction sites, oil fields, offshore platforms, and other locations where the electric utility grid is not available. Distributed Generation The microturbine produces synchronous current when connected to an electric utility grid. It allows electric utilities to expand power generation capacity in small increments, to optimize current infrastructure, and reduce or delay the need to develop, fund, and build new transmission and distribution lines. The Microturbine also allows utility consumers to offset part of their energy consumption from the grid. Heat Recovery Module The C200 Heat Recovery Module HRM accessory operates with the C200 microturbine to provide hot water heat recovery. The HRM is an exhaust economizer with integral temperature setpoint controller and exhaust diverter. The controller provides digital readout of water temperature leaving the heat exchanger, and allows the user to set the desired outlet temperature.



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An electrically operated exhaust gas diverter valve is actuated by the controller to maintain outlet temperature to the selected setpoint. Power for the controller and actuator can be supplied by the auxiliary electrical output of the C200. Operational Features Operational features of the Capstone C200 microturbine are summarized in the following Peak Shaving The microturbine can augment utility supply during peak load periods, thus increasing power reliability and reducing or eliminating peak demand charges. Combined Peak Shaving and Standby The microturbine can be used for both Grid Connect power and Stand Alone power for protected loads. The microturbine, with its low emissions, low maintenance requirements, and high reliability is well suited for combination peakshaving and standby power applications Rev C June 2009 23 This MultiPac capability enables connected microturbines to operate as a single power generation source. A MultiPac configuration features a single control point and synchronous voltage and frequency output for all units. Individual microturbines share power, current, and load on both a dynamic and steady state basis. An optional Capstone Advanced Power Server APS can be used to manage the power distribution for more than 20 microturbines. C200 models are available that can accept Sour Gas with up to 5000 ppmv Hydrogen Sulfide H 2 S content. This application helps reduce pollution and provides economical power for onsite use as a byproduct. Thermal Heat Recovery The oxygenrich exhaust from the microturbine can also be used for direct heat or as an air preheater for downstream burners. The optional C200 HRM allows commercial businesses to offset or replace local thermal loads such as domestic hot water, space heating, pool heating, and industrial hot water.

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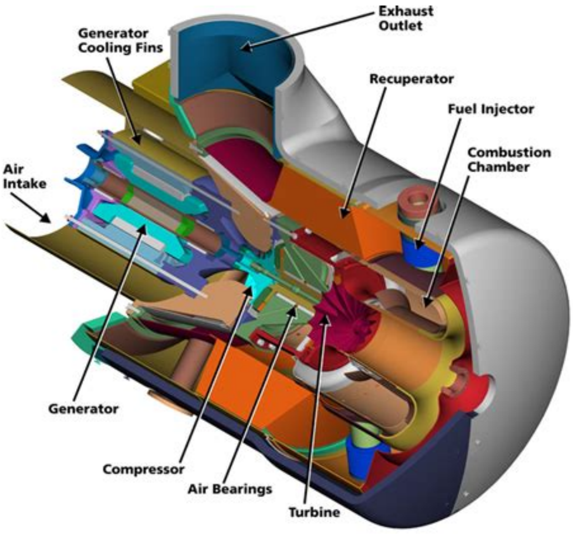

In addition, the oxygenrich exhaust together with ultralow emissions makes the direct exhaust applicable for some food processing and greenhouse uses, such as heating, cooling by absorption, dehumidifying, baking, or drying. OEM Applications The microturbine core technology can be integrated into a wide variety of products and systems. Uninterruptible power supplies, allinone combined heat and power systems, and welding machines are just a few examples of OEM applications. Output Measurements The measurements presented in this document are mostly in metric units with U.S. standard units in parentheses. Refer to the sections below for more data. ISO Conditions Combustion turbine powered devices including the Capstone microturbine are typically rated at 15 C 59 F at sea level, or 1 atmosphere 1 atm which is 760 mm Hg psia and identified as International Standardization Organization ISO conditions. For a complete definition of ISO testing conditions, refer to ISO Pressure Pressure figures assume gauge pressure, or 1 standard atmosphere 1 atm 760 mm Hg psia less than absolute pressure, unless otherwise indicated. Volume Fuel gas and exhaust gas volumetric measurements are given in normalized cubic meters m 3 , defined at 0 C 32 F, and standard cubic feet scf, defined at 15.6 C 60 F. Both volumes are defined at 1 atm 760 mm Hg, psia Rev C June 2009 24 Capstone calculates heating values at 1 atmosphere atm and 15.6 C 60 F, according to ASTM D3588. Microturbine Performance The microturbine electrical output capability is reduced when operating in higher ambient temperatures or elevations, and by intake or exhaust restrictions. Refer to Chapter 7 Performance in this document for details. Grid Connect Output The microturbine electrical output in Grid Connect mode is 3phase, 400 to 480 VAC and 50 to 60 Hz both voltage and frequency are determined by the electric utility grid.

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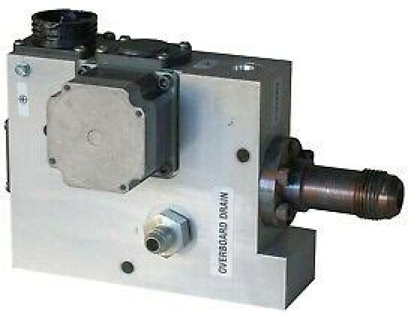

Allowable connection types include a 4wire wye either solidly grounded or grounded through a resistor. For neutral ground resistor requirements refer to CHAPTER 8 Electrical Ratings Grid Connect. Stand Alone Output When equipped with the Stand Alone option, the electrical output is useradjustable from 150 to 480 VAC and from 45 to 60 Hz. The output power need not be balanced. Loads can be connected 3phases or single phase and phasetophase or phasetoneutral, so long as the current limits of each phase are respected. Refer to CHAPTER 8 Electrical Ratings Stand Alone in this document for more details. Power Quality The microturbine output conforms to IEEE, IEEE Recommended Practices, and Requirements for Harmonic Control in Electrical Power Systems. Refer to CHAPTER 8 Electrical Ratings in this document for more details. Heat Output The recuperated microturbine can produce up to 1,420,000 kj 1,350,000 Btu per hour of clean, usable exhaust heat in the range of 232 to 310 C 450 to 590 F. The microturbine exhaust stream is 305 mm 12 in in diameter, flowing up to 62 normal m 3 2300 scf per minute. Refer to CHAPTER 7 Performance in this document for more details Rev C June 2009 25 The use of air bearings, coupled with the fact that the microturbine system does not incorporate a mechanical transmission, means that no lubricants or coolants need to be periodically replaced or disposed of. Refer to Chapter 11 Maintenance in this document for details, including expected battery life for Stand Alone systems. Certifications, Permits, and Codes The Capstone C200 microturbine is designed and manufactured in accordance with a variety of national and international standards, including Underwriters Laboratories UL, the American National Standards Institute ANSI, European Norms EN, the Institute of Electrical and Electronic Engineers IEEE, and the California Air Resources Board CARB.

For detailed information on the requirements of each authority having jurisdiction and how the Capstone microturbine meets those requirements, contact your Capstone Authorized Service Provider for assistance and the latest Capstone microturbine Compliance List Rev C June 2009 26 The integrated microelectronic controllers synchronize with the electric utility and provide utility protection, thereby eliminating the need for additional third party protective equipment. The C200 is based on the same proven architectural concepts as the Capstone Model C65 microturbine. The C200 has an extremely high power density due to the high rotational speed of its permanent magnet generator. The C200 has high electrical efficiencies for a turbine because it incorporates an air to air heat exchanger, called a recuperator. By recovering exhaust waste heat, and using it to preheat combustion air, the recuperator reduces the amount of fuel consumed by a factor of two. Major C200 Functional Elements The major functional elements that make up the Capstone C200 microturbine system are shown in Figure 31. EXHAUST MAIN OUTPUT COMBUSTION AIR MICROTURBINE ENGINE HIGH POWER ELECTRONICS ELECTRICAL OUTPUT AUX OUTPUT FUEL SOURCE FUEL SYSTEM SYSTEM CONTROLS USER INTERFACE AND COMMUNICATIONS Figure 31. Major C200 Functional Elements Rev C June 2009 31 The rotating components are mounted on a single shaft supported by patented air bearings and spin at a maximum speed of 60,000 RPM. The permanent magnet generator is cooled by the airflow into the microturbine. The output of the generator is variable voltage, variable frequency AC. The generator is used as a motor during startup and cooldown cycles. Fuel System The microturbine can efficiently use a wide range of approved hydrocarbonbased gaseous fuels, depending on the model. The microturbine includes an integral fuel delivery and control system. The standard system is designed for pressurized hydrocarbonbased gaseous fuels.

Other models are available for lowpressure gaseous fuels, gaseous fuels with lower heat content, gaseous fuels with corrosive components, and biogas landfill and digester gas fuels. Contact your Capstone Authorized Service Provider for data on approved fuels and performance specifications. Power Electronics Digital power electronics control and condition the microturbine electrical output.

The digital power electronics change the variable frequency AC power from the generator to DC voltage, and then to constant frequency AC voltage. During startup, the digital power electronics operate as a variable frequency drive, and motor the generator until the microturbine has reached ignition and power is available from the microturbine. The digital power electronics again operate as a drive during cooldown to remove heat stored in the recuperator and within the microturbine engine in order to protect the system components. Electrical Output The C200 microturbine provides two electrical output connections The main 3phase AC power, which can provide up to 200KW An auxiliary 3phase AC output, which can provide up to 10 kva prior to the main power becoming available. The auxiliary power can be used for short periods of time to drive smaller three phase AC loads from the optional battery system, such as an external fuel gas booster or heat recovery system water pump. System Controls The digital system controls govern the operation of the microturbine Generator and all electronic subsystems, including the high power electronics, the fuel system and electrical output module Rev C June 2009 32 The system comes equipped with a wide array of digital input and output connections to facilitate full integration into any Building Management System, Supervisory Control and Data Acquisition SCADA or Programmable Logic Controller PLC based application. Options are available to communicate with the microturbine via RS232 serial communications, telephone modem, or internet.

The microturbine can be monitored, as well as commanded with optional interfaces. Fault codes are accessible over the various communication links to assist with remote troubleshooting. Exhaust Clean hot exhaust air can be used for process heating or cooling and can increase the overall efficiency of the system. This exhaust may be directed to an optional air to water heat exchanger. Alternately, the exhaust may be directed to customer provided devices, such as absorption chillers, which can generate cold water from the hot exhaust. Control System Components The C200 microturbine is controlled by multiple proprietary digital controllers that work in unison to deliver the required power for the user. The system runs in one of two primary operating modes. The first mode is called Grid Connect where the system will generate power at the level requested by the user and deliver it to the existing, active power grid in the user s facility. The other mode of operation is Stand Alone. In Stand Alone, the microturbine is the sole source of electrical generation and generates the power necessary to support whatever load is connected to it as long as the load is below the maximum capacity of the generator. There are five primary independent digital controllers in the microturbine systems that are responsible for their own specific task. These are Load Controller, located in the Load Control Module Generator Controller, located in the Generator Control Module Engine Controller, located in the Fuel Metering Module Two identical Battery Controllers, one in each Battery Control Module System Controller, located in the System Control Module. Connecting these controllers are a low voltage DC bus and a communication bus. Power and communication between these controllers flow over these bus connections as can be seen in Figure 32. Each of the major components has a Personality Module PM embedded in it.

The PM is an Electrically Erasable Programmable Read Only Memory EEPROM device which is used to store operational parameters and user settings for each of these components. This allows the main operating software to identify, and adjust for the operation of, various machine configurations. These PMs can be read and programmed through the CRMS Software. Refer to the CRMS Technical Reference, Maintenance Edition 410014 for PM upload and download instructions Rev C June 2009 33 22 CHAPTER 3 SYSTEM DESCRIPTION Figure 32. Major Microturbine System Components Rev C June 2009 34 23 CHAPTER 3 SYSTEM DESCRIPTION Load Controller The C200 Load Controller is one of the primary digital controllers and is responsible for converting power from the high power DC bus to the customer s desired AC output voltage and frequency or in the reverse direction in order to start the engine. In the case of a Grid Connect system, the Load Controller automatically matches the existing voltage and frequency of the customer s grid. This controller provides high frequency AC power to initially spin the engine up to the desired starting speed by flowing power from the DC bus. Once the system lights off, it controls the speed of the engine ensuring that the system remains at the speed to which it was commanded in order to generate power. Then Generator Controller then transfers that power to the DC bus. This controller also has control of the safety valve that opens and dumps compressed air overboard in the event of a loss of speed control, and a brake resistor that can be used to control excess power on the DC bus. Engine Controller The C200 Engine Controller is responsible for regulating fuel, the igniter, and all engine sensors. It initiates the lighting sequence of the engine and then controls the operating temperature with the flow of fuel once ignition is detected. Controlling of the fuel also includes control of the flow to the six individual fuel injectors.

Battery Controllers The C200 has two identical Battery Controllers that convert the battery DC bus voltage from two large DC batteries to the system high power DC bus voltage. These controllers are responsible for the sourcing or sinking of power as necessary to regulate the DC bus. These controllers are only found on Stand Alone systems as the inverter regulates the DC bus on grid connect systems using grid power. During a start on a Stand Alone system, the Battery Controllers are responsible for turning on and charging the system s high power DC bus. They also have built in battery health and monitoring software to manage the charge of the system s batteries. System Controller The C200 System Controller is responsible for management of the entire microturbine operation and the interfacing to the outside world. It commands the individual controllers to the correct operation states and operation settings at the proper time to regulate the entire system. It takes manual commands from the user through the Display Panel, digital commands over the RS232 communication bus using the Capstone Remote Monitoring System CRMS software from a computer or from a MODBUS converter, MultiPac communication from another turbine, Advanced Power Server, or direct discrete analog or digital inputs. This controller logs all system faults and records data prior to, during, and after all logged faults for the last 20 faults on record. As an additional safety feature, it has control of all low voltage DC power to the fuel valves and will disable the fuel system, independent of the Engine Controller, in the event of a fault Rev C June 2009 35 24 CHAPTER 3 SYSTEM DESCRIPTION Operational States Figure 33 and Figure 34 show the C200s operational states and all possible transitions between states. The transitions and active states can be different between Grid Connect and Stand Alone operation.

The fault logic will transition directly out of any state into the Disable, Warmdown, or Fault state depending upon the severity of the fault. If the user initiates a download of new software, then the system transitions to the Software Download state and remains there until the system is restarted to ensure that the power is cycled after downloading new software. This cycle of power is also required if the system ever faults out and ends up in the Disable state. Power Up The StartUp sequence differs for Grid Connect and Stand Alone modes For Grid Connect, the user needs to provide power from the Grid Connection to the main electrical terminal connections on the microturbine. Once power is applied, the system s DC bus precharge circuit powers up the main DC power bus that supplies power to the 24 VDC power supplies. These power supplies provide power throughout the system to all the individual digital controllers putting the system into the Power Up control state on the main controller. For Stand Alone, the user presses the Battery Wakeup button on the Display Panel or closes the external battery wakeup circuit momentarily. This circuit applies the 12 V power from the small battery in the user connection bay to the battery controllers, latching a contact that enables the precharge circuit in the battery controllers to activate the battery s main controller. The battery s main controller then energizes the system s primary DC bus using power from the main batteries. The system then starts up the same way as the Grid Connect system. While in the Power Up state, the System Controller goes through all of its system checks, checks that all other controllers have also passed their system checks, and checks that it has the correct hardware connected for this type of system. It then checks the hardware inputs to determine if it is configured to be a Grid Connect, Stand Alone, or Dual Mode system.

If there are errors during this process, then the system transitions to the Invalid state. If the jumpers and hardware are correct, the system transitions to the Stand By state Rev C June 2009 36 25 CHAPTER 3 SYSTEM DESCRIPTION Figure 33. System Operational States Grid Connect Rev C June 2009 37 26 CHAPTER 3 SYSTEM DESCRIPTION Figure 34. System Operational States Stand Alone Rev C June 2009 38 27 CHAPTER 3 SYSTEM DESCRIPTION Invalid This is the state the system transitions to when the software or hardware does not match or if there have not been any jumpers installed to identify the mode in which to run. New systems are delivered in this manner and will end up in this state upon initialization. Stand By This is the primary state for the microturbine after power up or anytime the unit is on but not issued a Start command. For Grid Connect, the system will stay in this state as long as grid power is applied to the terminals. For Stand Alone, the system has a timer that will turn off the power and wait for a battery wakeup command to start back up after the timer expires. This timer is user adjustable. Burn In This state is used to burn in new power electronics during production build. Idle Recharge This state is available for Dual Mode or Standby systems that have batteries but do not run in Stand Alone mode except in the very rare instances of a power outage. The user can command the system to this state to charge the main batteries. The microturbine uses power from the grid to perform a complete charge of the batteries in order to maintain their health. Cooldown This state is transitioned to if the power electronics are too hot and need to be cooled down prior to starting the system. Prepare to Start This state prepares the system to run at power. It sets the proper operating modes and then enables the Load Controller, Generator Controller, and Battery Controllers if present. Once these are functioning correctly, the primary cooling fan is powered.

Liftoff In this state, the Generator Controller is commanded to bring the engine quickly up to its start speed. Once this speed is reached successfully, the Generator Controller is put in speed control mode and the system transitions to the next state in the sequence. Light This is the state where the combustion system is ignited. The System Controller commands the Engine Controller to initiate the light sequence. The Engine Controller enables the igniter and ramps the flow of fuel at the proper rate for the customer s fuel type until ignition is detected. Once the system controller detects the lightoff, the System Controller places the Engine Controller in closed loop temperature control and transitions to the next state Rev C June 2009 39 28 CHAPTER 3 SYSTEM DESCRIPTION Acceleration The system controller waits in this state until the Generator Controller has transitioned the engine speed up to the minimum engine idle speed before transitioning to the next state. Run This is the state the system stays in until the engine is fully warmed up and the load command is set by the user. Once both of these conditions are met, the System Controller transitions to the Load state. Load In this state, power is generated out of the system. In Grid Connect, the system will meet the commanded demand of the user. In Stand Alone, the system will support the entire load connected to the microturbine up to the limit of the microturbine output. Recharge Hot Standby This state is only active for Stand Alone systems. In Stand Alone, it is critical to make sure the batteries are charged prior to shutting down. Therefore, the System Controller disables the main output power, but continues to produce power with the engine thus allowing the battery controllers to fully charge the main system batteries. The time for this charge will vary with the existing health of the batteries at the time of shutdown. Once the batteries are fully charged, the System Controller continues to the next state.