

## Using a Magnum MSH4024RE inverter with a PT-100 controller in a grid-assist system.



### What is a Grid-Assist System

In addition to normal grid power supplied by electric companies, solar panels, wind turbines, micro hydro generators, and batteries can also be used. There are various system configurations depending upon the total electrical load, available budget, and desired objectives.

One way to think about solar systems is are they connected to the electrical grid or not. Some typical system configurations are:

- **Grid-Connected/Net metering systems** - These systems power some or all of the electrical loads plus they sell any excess power generated back to the utility company. As such they typically have a large number of solar panels. However they use grid power at night and on cloudy days. They do not include an inverter with batteries for emergency power when grid power is not available. The net savings is dependent upon the rates set by the local electric company and, as such, the rates could rise in the future.
- **Off-grid systems** - These systems are designed to run all electrical loads for 24 hours a day. As such they typically require large battery and solar panel arrays. They may also have wind turbines and, if a creek flows across the property, a micro hydro generator. By their very nature they have power during all emergencies.
- **Grid-assist systems** - These systems are designed to reduce overall electrical costs by powering critical/essential circuits on sunny days while using normal grid electricity at night and during cloudy days. A grid-assist system includes a moderate battery backup for occasional power outages that are short term in duration. If desired, a small generator can be added for long term power outages. In addition to solar panels, wind turbines or/and micro hydro generators can also be used.

In summary, a grid-assist system gives a homeowner a modest but sufficient emergency power source while at the time reducing overall electrical costs. This is unlike a whole house emergency generator which might rarely be used and which requires regular maintenance.

## **How to plan for a Grid-Assist System**

To be an effective solution, a homeowner first must do an energy audit and then change or upgrade devices to reduce the overall electrical usage. In addition to light bulb changes, the homeowner should consider such options as converting to a tankless gas water heater, improving attic insulation, and upgrading appliances to more energy efficient units.

Some major devices will need to remain on grid power. These include house air conditioning systems, electric stoves, electric clothes dryers, and well pumps. Also some sections of the house might be rarely used and thus should remain on grid power. A larger generator could be utilized for some of these if long term power outages were a frequent occurrence and alternate solutions such fans or gas cooking were not available. The desired goal is to reduce dependance on 240 volt, high amperage devices so that you can survive for a week or more during a major electrical outage while using solar energy plus a small generator. A properly designed grid-assist system will keep your refrigerators and freezers running.

After the energy audit and the device upgrades are completed, the potential critical/essential circuits can be monitored on the main panel to determine the minimum, nominal, and maximum power consumption in amps for each. High wattage devices such as hair dryers, electric irons, etc. can be supported as long as they are not on for an extended period of time, especially when no sun is available. The total nominal load should be used to determine the estimated number of solar panels needed. The typical limiting factor is the size of a south facing roof or/and south facing open section of land to mount the solar panels.

Normally a single 4000 watt Magnum MSH-4024RE inverter plus a Magnum PT-100 solar charge controller should be sufficient for a grid-assist system. A single PT-100 controller can support a large solar panel array up to 6600W - approximately 24 solar panels of 285 watts each. Typical grid-assist systems will need between 6 and 12 solar panels depending upon the electrical load.

Various battery sizes are available up to 400 amp-hours for a set of 4 six volt batteries. Additional sets of 4 batteries can be added if the system needs to operate longer without a generator during emergencies. AGM batteries, although more expensive, are nice because they are maintenance free. As time progresses Lithium batteries will become more cost effective and available.

## **Example installation of a Grid-Assist System**

The following describes the 2015 installation in South Carolina of a MSH4024RE inverter, a PT-100 charge controller, six 285 watt solar panels (1,710 watts total), four 405 amp-hour AGM batteries, and a 30 amp generator connection outlet.

The location of the sub panel, inverter, charge controller, and batteries needs to be determined during the project planning stage. For this installation the customer decided to mount the inverter assembly on the rear garage wall and the batteries on the floor. The inverter assembly consisted of the inverter, charge controller, a Magnum ME-BMK Battery Monitor Kit, and a Magnum MMP175-60S Mini Panel all of which were mounted on a backplate.

The main electrical panel was on the opposite side of the wall, on a stairway going to the bonus room over the garage. The sub panel and Magnum Advanced Remote Control were mounted next to the main panel. This provided convenient access from inside the house.

The solar panels were mounted on the south facing garage roof and a Midnight Solar combiner panel mounted near the garage door. The generator connection was added to the junction box below the combiner panel. The customer simply runs an extension cable from his RV to the generator connection and uses his RV's generator during extended electrical outages while at home. While traveling the batteries and solar are sufficient for most short term outages.

After the critical circuits were measured and selected, they were moved to the sub panel as a first step in the installation process. This was done in the Spring of 2015 while a tankless gas water heater was installed. (The 25 year old electric heater had died the month before.)

A 60 amp breaker was installed in the main panel and connected to a 60 amp breaker in the sub panel. The current draw between the 60 amp breakers was monitored to verify that the sum of the previously measured load values matched the actual load on the sub panel. After the inverter assembly was mounted on the wall, the main breaker was connected to the AC1 input of the inverter and the sub panel breaker was connected to the inverter output.

The customer requested a custom, pre-built system from Wholesale Solar but could not place the order until the PT-100 was released to production. The order was placed in August and the system shipped in October. The installation was completed in November.

### **Setup details of the example system**

The key MSH4024RE inverter feature for a Grid-assist system is **Load Support VDC**. In this mode, an external DC source (i.e., solar, hydro, wind, etc.) is providing more current than needed, causing the battery bank voltage to rise. The inverter/charger reduces the incoming AC current and uses current from the batteries in an effort to keep the battery voltage from rising above the temperature-compensated battery type setting on the remote control.

For the Load Support feature to automatically function, the following needs to occur:

1. An AC source (utility grid or AC generator) must be connected.
2. The inverter must be enabled (INV LED is on).
3. The battery voltage must be  $\geq 1.0$  volts (for a 24-volt system) than the LBCO (Low Battery CutOff) setting.

**Info:** The charger must be enabled (not in Charger Standby) and in the Absorb, Float, or EQ charge modes in order for the Load Support VDC feature to be active.

**Info:** If using a remote and the unit is in load support, the status will display as “Load Support VDC”.

There are two important issues/problems based upon the above requirements:

1. The inverter's charger must be enabled.  
By default the MSH4024RE inverter uses a four stage automatic charger: Bulk - Absorb - Float - Full Charge. The inverter charger is off when in Full Charge state. The PT-100 charge controller has a 3 stage charger: Bulk - Absorb – Float
2. The solar charge controller must be providing more current than needed.  
By default the PT-100's charge parameters are set to be the same as the inverter's parameters.

## MSH4024RE inverter charge states

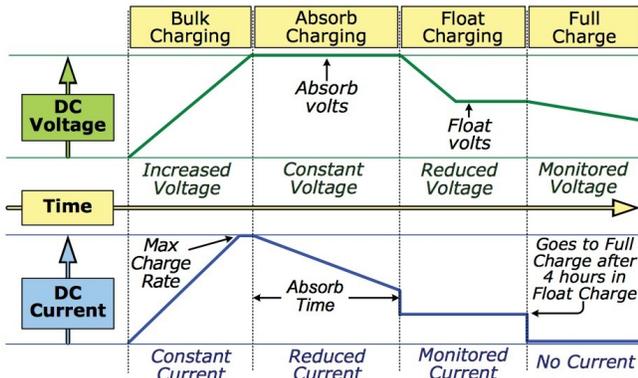


Figure 3-4, Automatic 4-Stage Charging Graph

## PT-100 Charge States

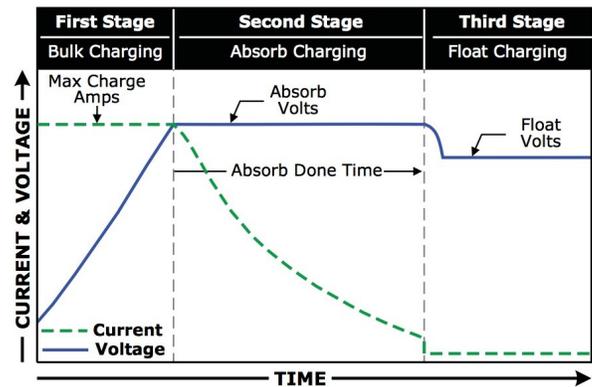


Figure 4-9, Automatic 3-Stage Charging Graph

**Bulk Charging:** This is the initial stage of charging. While bulk charging, the charger supplies the battery with controlled constant current. The charger will remain in bulk charge until the absorption charge voltage is achieved. The PT-100 controller begins each new day in the Bulk charge stage (new day = 2 hours without sun).

**Absorb Charging:** This is the second charging stage and begins after the absorb voltage has been reached. Absorb charging provides the batteries with a constant voltage and reduces the DC charging current in order to maintain the absorb voltage setting.

**Float Charging:** The third charging stage occurs at the end of the absorb charging time. While float charging, the charge voltage is reduced to the float charge voltage. In this stage, the batteries are kept fully charged and ready if needed by the inverter. The Float Charging stage reduces battery gassing, minimizes watering requirements (for flooded batteries), and ensures the batteries are maintained at optimum capacity.

**Full Charge (Battery Saver mode):** The fourth stage occurs after four hours in the Float Charging stage. The Full Charge stage is designed to keep batteries fully charged over long periods, and to prevent excessive loss of water in flooded batteries or drying out of GEL/AGM batteries. In this stage, the charger is turned off and begins monitoring the battery voltage; if the battery voltage drops low (25.4 VDC or less), the inverter charger automatically initiates another four hours in float charge.

**Info:** If the battery voltage falls to the re-bulk voltage (24.2 VDC) or lower, the unit will begin another bulk charge.

## Required Changes:

1. The inverter's final charge state must be changed to Float.
2. The PT-100 charge parameters must be un-linked from inverter charge parameters.
3. Custom battery settings are required for both inverter and PT-100 so that PT-100 has a higher charge voltage. That is, the PT-100 charge voltage must be higher than the inverter's max charge voltage so that Load Support VDC is activated.

## How to un-link the PT-100 charge parameters

Press Setup button and choose **SETUP: 01 System Setup**

### **01E Link PT CHG Settings –**

This menu is used to link the PT charging settings (06A Battery Type and ~~06D~~ 06B{*manual error*} Absorb Done) with the inverter's charger settings (03C Battery Type and 03D Absorb Done Time). When linked, the inverter's charger settings are used to determine how the inverter/charger and the PT controller will charge the battery.

Default setting: YES

Range: YES, NO

**Note:** If “YES” is selected, the link feature is enabled and the PT charging settings (06A Battery Type and 06D Absorb Done) display “Linked,” and are locked and prevented from being adjusted.

**What is the Link feature?** A method of managing common battery charging settings among multiple chargers (i.e., the inverter's charger and the PT controller). The link feature provides the ability to link charger settings and to manage/coordinate all charging devices from a system level perspective; or alternatively, to be unlinked and to allow individual charger device control.

**Why turn the Link feature off?** You might want to unlink when the inverter's charge voltage is not high enough and the higher PT controller charge voltage setting is required.

- - - - > **Change setting to NO** <- - - -

## How to change the final charge state

Press Setup button and choose **SETUP: 03 Charger Setup**

### **03G Final Charge Stage –**

This setting determines what charge stage(s) occurs after the Absorption Charge stage has finished.

Default setting: Multi

Range: Multi, Float, Silent

#### ◇ **Set Final Charge Stage = Multi –**

The Multi setting (which is short for “Multi-Stage”), transitions from the Absorption charge stage to the Float charge stage. Once in the Float stage for four hours with no DC load on the batteries, the charger will enter the Full Charge stage (i.e., Battery Saver mode). In Full Charge mode, the charger automatically stops charging but is still on and actively monitoring the battery voltage. The charger will remain in the Full Charge stage until the battery voltage drops below 25.4 VDC for 24-volt batteries—at which time it will return to the Float stage.

#### ◇ **Set Final Charge Stage = Float –**

The Float stage is a maintenance charge mode that maintains a constant voltage while delivering up to the maximum rated current of the charger in order to power any DC loads connected to the batteries. Most 3-stage chargers finish the charge mode in Float, and remain in Float as long as an AC source is available on the input of the charger.

- - - - > **Change setting to Float** <- - - -

## How to change the inverter's absorb done setting

Press Setup button and choose **SETUP: 03 Charger Setup**

### **03D Absorb Done (Time, Amps, SOC) –**

This setting identifies whether time, amps, or SOC are used to determine when the second stage of battery charging (Absorption) is finished. The charge cycle transitions to the final charge stage (03G Final Charge Stage) afterwards. Absorption is the second stage of the charge process that attempts to fully charge the batteries.

Default setting: Time (2-0 Hrs)

Range: Time, Amps, SOC

#### ◇ **Set Absorb Done = Time –**

*Absorb Done Time* is used when a specific time is determined to be best for ending the Absorption stage.

Default setting: 2.0 Hrs

Range: 0.1-25.5 Hrs

#### ◇ **Set Absorb Done = Amps –**

*Absorb Done Amps* is used when the DC amperage supplied to the batteries (also known as “return amps”) is used to determine when the batteries are fully charged.

Default setting: 20 Amps DC

Range: 0-250 Amps DC

#### ◇ **Set Absorb Done = SOC –**

*Absorb Done SOC* can be used if a battery monitor kit is installed and you want to use the SOC (State of Charge) of the battery bank to determine when the batteries are fully charged.

Default setting: 100%

Range: 50-100%

**Note:** The SOC is the best way to determine when the batteries are fully charged, and is helpful because any DC loads or other charge sources connected to the battery bank will not affect the SOC reading.

**Info:** If the Absorb Done SOC setting is used when charging from a generator source, then it is recommended that a setting of less than 100% be used (usually around 90% is acceptable). Running the generator higher than the 90% setting is sometimes considered an inefficient use of fuel.

**Info:** If the Absorb Done SOC setting is active, the charger will go into Bulk charge mode each time AC is connected.

**----- > Change setting to Absorb Done SOC - 100% <-----**

## How to change the inverter's absorb done

Press Setup button and choose **SETUP: 06 PT Setup**

### **06B Absorb Done (Time, Amps, SOC) –**

This setting's description and values are the same as **03D** described above. When Linked via **01E**, the PT-100 uses the same setting as the inverter. It must be verified and changed when Un-Linked.

**--- > Change setting to Absorb Done SOC - 100% <---**

## Understanding and choosing the battery charge settings

Let's look at the specs for the Full River DC400-6 battery.

CHARGE VOLTAGES				
	Battery Voltages			
Charge Stage	12V	24V	36V	48V
Bulk	14.7V	29.4V	44.1V	58.8V
Absorption	14.7V	29.4V	44.1V	58.8V
Float	13.6V	27.2V	40.8V	54.6V
TC Factor: (-2mV°F/cell) or (-4mV°C/cell)				

Now let's look at the manual for the Magnum remote. AGM 2 is as close as you can get, but not ideal.

**Table 3-1, Battery Type to Charge Voltages (fixed voltage)**

Battery Type	Inverter Voltage	Absorption Voltage	Float Voltage	Equalization Voltage
GEL	12 VDC	14.1 VDC	13.6 VDC	14.1 VDC <sup>1</sup>
	24 VDC	28.2 VDC	27.2 VDC	28.2 VDC <sup>1</sup>
	48 VDC	56.4 VDC	54.4 VDC	56.4 VDC <sup>1</sup>
Flooded	12 VDC	14.6 VDC	13.4 VDC	15.5 VDC
	24 VDC	29.2 VDC	26.8 VDC	31.0 VDC
	48 VDC	58.4 VDC	53.6 VDC	62.0 VDC
AGM 1 <sup>2</sup>	12 VDC	14.3 VDC	13.1 VDC	15.5 VDC
	24 VDC	28.6 VDC	26.2 VDC	31.0 VDC
	48 VDC	57.2 VDC	52.4 VDC	62.0 VDC
AGM 2 <sup>3</sup>	12 VDC	14.5 VDC	13.5 VDC	14.5 VDC <sup>1</sup>
	24 VDC	29.0 VDC	27.0 VDC	29.0 VDC <sup>1</sup>
	48 VDC	58.0 VDC	54.0 VDC	58.0 VDC <sup>1</sup>

**Note<sup>1</sup>:** Voltage same as absorption voltage—to prevent equalization.

**Note<sup>2</sup>:** Charge voltages for Concord (Lifeline Series) AGM batteries.

**Note<sup>3</sup>:** Charge voltages for East Penn, Deka, Discover, and Trojan AGM batteries.

Wholesale Solar Tech Support suggested going with Battery Type **CUSTOM** and setting:

- Absorb = 29.4 VDC
- Float = 27.2 VDC
- EQ = 29.4 VDC

*(The high EQ is why we can't just use the flooded setting. Also we don't EQ AGMs).*

## How to change the inverter's battery type settings

Press Setup button and choose **SETUP: 03 Charger Setup**

### 03C Battery Type –

This setting selects the battery type, which determines the battery charge profile and ensures the batteries are receiving the proper charge voltage. The charge voltage settings are fixed when using the *GEL*, *Flooded*, *AGM1*, or *AGM2* selections, but can be adjusted if using the *CC/CV* or *Custom* selections.

**Default setting:** *Flooded* –

**Range:** *AGM1, AGM2, Flooded, GEL, CC/CV, Custom*

◇ **Set Battery Type (GEL, Flooded, AGM1, or AGM2)** – When the battery type selection is *GEL* (for Gel batteries), *Flooded* (for liquid lead acid batteries), *AGM1* (for Lifeline AGM batteries), or *AGM2* (for East Penn/Deka/Discover/Trojan AGM batteries), the charge voltage level for the Absorption, Float, and EQ charge modes are fixed and shown in Table 3-1.

◇ **Set Battery Type (CC/CV)** – The *CC/CV* selection provides a Constant Current/Constant Voltage (*CC/CV*) charging method with an adjustable charge voltage.

◇ **Set Battery Type (Custom)** – This selection allows you to individually adjust the Float, Absorb, and Equalization charge voltage settings and to set an equalization time for your batteries. The following Custom battery settings display only if *Custom* has been selected from the *03 Battery Type* menu. Use these settings to determine the battery's absorption, float, and equalization voltages, and the maximum amount of time spent equalizing.

- - - - > **Change setting to Custom & set the specific values below** <- - - -

- **Absorb Volts** – Sets the level at which the charging voltage is held constant during an Absorption cycle.  
**Default:** *28.8V (24v)* – **Set to 29.4**  
**Range:** *24.0-32.0V (24v)*
- **Float Volts** – Sets the level at which the charging voltage is held constant during a Float cycle.  
**Default:** *26.4V (24v)* – **Set to 27.2**  
**Range:** *24.0-32.0V (24v)*
- **EQ Volts** – Sets the level at which the charging voltage is held constant during an Equalization cycle.  
**Default:** *31.2V (24v)*– **Set to 29.4**  
**Range:** *24.0-32.0V*
- **EQ Done Time** – Sets the time (duration) the battery will charge at the *EQ Volts* setting.  
**Default:** *4.0 Hrs* **Range:** *0.1-25.5 Hrs*

## How to change the inverter's battery type settings

As noted previously, the solar charge controller must be providing more current than needed.

By default the PT-100's charge parameters are set to be the same as the inverter's parameters. Therefore the battery type must also be set to CUSTOM and the charge voltages set higher than the voltages set for the inverter's charger. From Magnum Tech Support:

Charger and Inverter must be on and your PV must raise the voltage above the inverters/chargers temperature target voltage for whatever charge mode it is in at the time. Within 4 to 10 seconds you should see Load Support VDC as the status on the display and as long as the voltage stays up it will decrease amps in from grid. We don't have an exact voltage that is has to be above the target but I would say **at least a half of volt to a volt** to be safe.

Press Setup button and choose **SETUP: 06 PT Setup**

**06A Battery Type** – This setting's description and values are the same as **03C** described above.

- - - - > **Change setting to Custom & set the specific values below** <- - - -

- **Absorb Volts** – Sets the level at which the charging voltage is held constant during an Absorption cycle.  
**Default:**  $28.8V$  (24v) – **Set to  $29.4 + 0.5 = 29.9$  volts**  
**Range:**  $24.0-32.0V$  (24v)
- **Float Volts** – Sets the level at which the charging voltage is held constant during a Float cycle.  
**Default:**  $26.4V$  (24v) – **Set to  $27.2 + 0.8 = 28.0$  volts**  
**Range:**  $24.0-32.0V$  (24v)
- **EQ Volts** – Sets the level at which the charging voltage is held constant during an Equalization cycle.  
**Default:**  $31.2V$  (24v)– **Set to ~~29.4~~ (29.8 was the lowest value available)**  
**Range:**  $24.0-32.0V$  (*Not important because EQ not used with AGM batteries*)
- **EQ Done Time** – Sets the time (duration) the battery will charge at the *EQ Volts* setting.  
**Default:**  $4.0$  Hrs **Range:**  $0.1-25.5$  Hrs

## Initial Testing Results from early January 2016

- First day: After setting the parameters, Load Support VDC activated on a cloudy afternoon.
  - Sub panel load = 6 amps AC
  - Main panel feed to inverter = 5 amps AC
  - Solar input = 13.3 amps DC
- A few days later will a full sunny day. Load Support VDC did not activate.
  - Sub panel load = 2/3 amps AC
  - Main panel feed to inverter = 2/3 amps AC
  - *(Did not work with a low, 2 amp AC load at noon. Changed PV float to 28.6 but still did not)*  
This was still not sufficient to activate Load Support VDC.
  - PV volts = 107.3 volts DC
  - PV amps = 30.4 amps DC
  - *(Still did not work with a low, Changed to Inverter float 26.4 but still did not)*  
This delta of 2.2 volts was still not sufficient to activate Load Support VDC.

## SUCCESS

- Increased load by turning on lights and hot water heater. Load Support VDC activated.
- Sub panel load = 15 amps AC
- Main panel feed to inverter = 7 amps AC
- PV volts = 82 volts DC
- PV amps = 46.2 amps DC
- PV battery voltage = 27.4 volts DC
- PV power to battery = 1,271.3 watts – approximately 75% of rated capacity

**Results after settings were changed on a cloudy afternoon in January**



**AC load = 6 amps AC**



**AC input (grid) = 5 amps AC**



**Solar panel output = 13.3 amps DC**



Results at 1:30 pm on a sunny afternoon (no clouds) in January



02C Input AMPS  
7 AMPS AC

02D Inv/Chg AMPS  
- 8 AMPS AC

07B PV Volts-PT  
82.0 UDC

07E Bat AMPS-PT  
46.2 ADC

07C Bat Volts-PT  
27.4 UDC

07D Target Volts  
30.0 UDC / 64F

07F Power to Bat  
Now: 1271.3 W