MORNINGSTAR
World's Leading Solar Controllers & Inverters

Solar Controller Integration with AC Rectifiers

Abstract

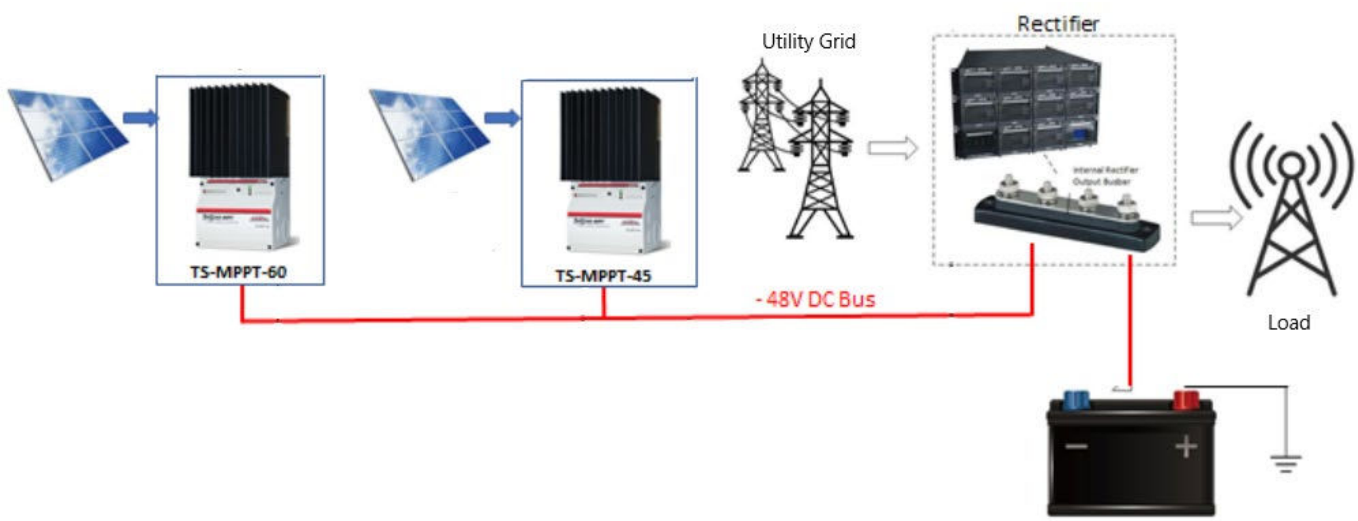
For over 25 years Morningstar solar controllers have been incorporated into off-grid and backup grid-tied systems. Many of these systems include a rectifier to charge a battery from an AC power source. This power source can be the utility grid or a generator. This paper will show how a solar PV system can be integrated into these types of rectifier systems. It will show how to configure Morningstar solar controllers with the rectifiers in order to get the most benefit out of the solar PV system. By prioritizing the use of solar energy over AC rectifier energy system owners can reduce their levelized cost of energy (LCOE) and still have reliable solar and battery backup power when AC power is not available.

Target Audience: Telecom system integrators, designers, and engineers

Solar Priority

<u>Grid Rectifier with Solar PV Backup Systems</u>

Telecommunications equipment is expected to operate without any interruptions. These systems incorporate energy storage and backup generators to take over the power needs during a power outage.



One Line diagram of Grid Rectifier with Solar PV Backup System

Having reliable energy during utility outages at these remote sites is critical. This is where solar can come into play to provide more reliable backup for longer power outages. For UPS/backup systems that do not have a generator the solar system will be the only means by which the battery bank will be charged during the outage.

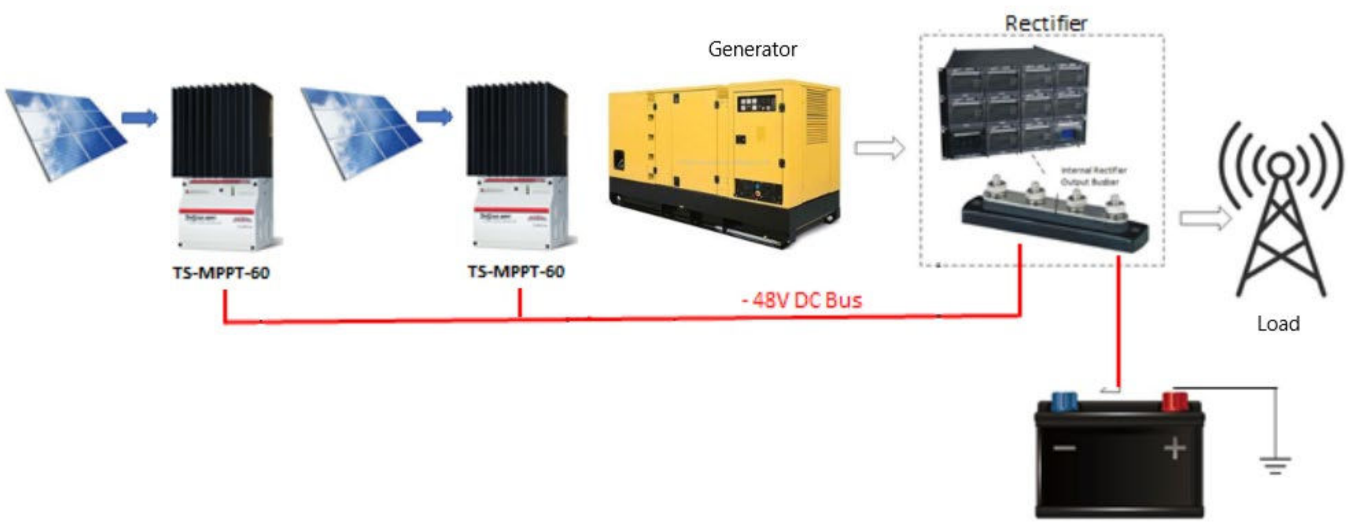
Many customers also want to use solar power during grid operation instead of utility to save utility costs. This is referred to as “solar priority” since it prioritizes the use of solar energy instead of utility energy. This could save a substantial amount in electricity charges over the life of the system and will help pay

for the solar installation and reduce the LCOE. Morningstar controller settings along with rectifier settings can have a big impact on how much solar energy is used instead of grid energy.

Solar Power Usage with Generators

One of the biggest challenges with off-grid solar PV systems is that the energy is not always available. Cloudy weather, winter months and other seasonal variations will greatly affect solar energy production. Battery banks can be sized larger to account for several days of autonomy when little or no solar power is available. Increasing the size of the solar array can also help the battery recover more quickly and keep the battery from getting discharged as much. Preventing the battery from being disconnected with solar energy alone can be quite costly. In addition, there is the risk that a critical fault with the solar PV equipment may occur. Therefore, the generator acts as backup to the PV array to keep the battery from over-discharging the battery as much and the loads from being disconnected.

Solar PV is also often added to off-grid generator systems to reduce generator run time greatly and keep the battery from cycling as much which can save a great deal of costs. See the “Benefits of adding solar to AC Rectifier systems” section at the end of this paper for additional benefits to add solar to an off-grid generator system.



One Line Diagram of Off-Grid Generator/ Rectifier with Solar PV System

Due to the way generator storage systems operate, coordinating the charge settings of the rectifier when operating with an AC generator is not of much concern. The solar power will continuously deliver as much power as it can without the generator taking over like a rectifier might in a utility backup system. Generators are generally set up so that the generator only starts when the SoC of the battery bank gets low. The solar PV system will supply power to these systems on an ongoing basis and minimize how often the generator needs to operate in order to power loads and recharge the battery. If the solar array is sized large enough to consistently bring the battery bank to a full SOC the generator can be used only for recovery from a very low SoC rather than to a full SoC like it would without the solar power. This reduces the generator run time greatly and coordinating the charge settings are not a concern. For systems that require the generator to help top off the battery coordinated settings can prevent the generator from taking over all of the charging during the final charging stages.

Types of Rectifiers

The most basic rectifiers available operate at a fixed output voltage. These rectifiers are considered a type of DC power supply and are used extensively with electronic equipment which requires DC power. When connected to a battery the rectifier will maintain battery voltage in order to keep the battery charged. Some rectifiers will include the ability to adjust the output voltage making it easier to coordinate with other charging equipment at the site.

More advanced rectifiers include a charging algorithm to better bring the battery bank to a higher state of charge than a single fixed voltage could. Coordinating the settings with the solar controller can be more difficult to accomplish and being able to adjust the charge settings of the rectifier will make a big difference in being able to utilize more solar energy.

Charging Coordination for Solar Priority

Solar controllers and rectifiers charge batteries in the same way. In fact, solar controllers are referred to as solar rectifiers also. These devices will continue to supply power to the battery circuit as long as the voltage is not higher than the regulation voltage. In order to implement Solar Priority is by coordinating the rectifier voltage settings with the solar controller(s) charging voltage settings. This will be considered mostly for utility backup systems. For generator rectifier systems where the generator gets shut off before it reaches a full SoC the solar controller can be set without concern with coordinating the rectifier and solar controller settings.

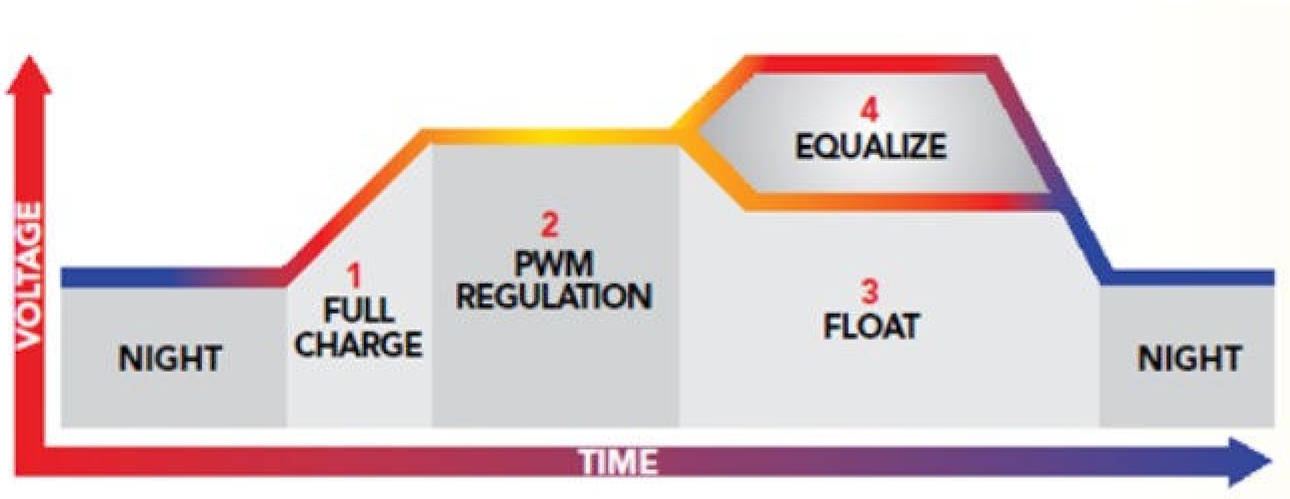
Whether special solar priority settings are being considered or not it is important to review the battery manufacturer's charge settings to ensure that the controller meets the charging requirements of the battery bank. This will ensure that the battery is not over or under charged, either of which can damage or reduce the cycle life of the battery bank.

Charge settings information of available presets are available in Morningstar product manuals. If custom programming is necessary Mornignstar's MSView software which includes a setup wizard for programming the charge settings. The following links are provided as references for configuring custom settings with Morningstar equipment.

MSView software download
Energy Storage Partner Program
Morningstar Custom Settings Info
Lead Acid Batteries Info
Lithium Batteries Info

3 Stage Charging Control

In order to prioritize solar charging over other charging sources it is important to understand the different battery charge stages. For the purpose of this paper we will consider 3 stage charging; Bulk, Absorption and Float.



Morningstar Charging Stage Algorithm

The initial bulk charging stage delivers maximum allowable current into the battery. As the battery reaches a higher state of charge the voltage will increase until it reaches the target regulation voltage which is based on the Absorption regulation voltage setpoint of the Morningstar solar controller. During the Absorption stage the controller is topping off the battery and the charging power will taper down as the battery bank reaches a full SoC.

The Absorption Time setting of the solar controller determines the amount of time the controller maintains the absorption voltage before it transitions to the Float stage where the voltage will be reduced to the Float Voltage.

It is important to note that the charge settings of Morningstar products include temperature compensation. This means that the target regulation voltage will rise with colder temperatures and lower with warmer temperatures.

Coordinating the Solar Charging with the Rectifier
Solar Priority requires that the target regulation voltage of the solar controller be higher than the charge/ regulation voltage of the regulator. If the rectifier is pulling the voltage higher than the target regulation voltage of the controller the rectifier power will take over to maintain the higher voltage. Therefore, it is useful to coordinate the voltage settings of the solar controller and the rectifier to keep the rectifier from operating with a higher voltage.

For utility backup systems the rectifier will operate with a fixed or float voltage most of the time. It is easiest to work around a rectifier with a fixed voltage that can be adjusted. In order to keep the solar controller's target regulation voltage higher than the rectifier voltage the controller's lowest target regulation voltage needs to be considered. If the regulator also includes temperature compensation it will also be affected by the temperature and this may not be an issue as much.

The minimum operating target regulation voltage will be based on the lowest voltage setpoint of the controller which is the Float voltage setpoint and the effect of the battery temperature compensation settings. This can be calculated as follows.

Vfloat + (TempHi X TempComp) = Min Vr
Vfloat - Float Voltage Setpoint
TempHi - Highest average ambient temperature
TempComp - Battery Temperature Compensation (V/degC)
Min Vr - Minimum Target Regulation Voltage

A low fixed voltage setting for the regulator voltage will work well. Therefore, using a rectifier that is not adjustable or has a single higher voltage setting can make coordinating solar priority settings achievable unless the rectifier can be disabled so the solar controller energy takes over completely. There are automation controls that can be used for this including the Morningstar Relay Driver which is discussed in the next section.

Maintaining a full SoC with the rectifier is not necessary since the solar array can top off the battery on a regular basis. Having it set at the rest voltage of the battery or slightly higher will keep the battery from discharging overnight and on cloudy days. Generally this is 12.6-12.7V for lead-acid batteries.

For utility systems that can maintain a full state of charge over long periods of time then it is important to consider adjusting the standard charge settings of the solar controller. This is because the charge settings of solar controllers are designed to fully recharge a battery bank for a system with daily cycling. We have a *Idle Battery Charge Settings* web page with downloadable configuration files which will work well with a utility backup system where the batteries will not be discharged on a daily basis. The main consideration is to extend the Adsorption Time only on days after the battery has been discharged. This can be achieved with a short Absorption Time setting with a long Absorption Time set with the Absorption Extension settings. This will make the battery briefly reach absorption and transition to float when the rectifier has been operating without an outage.

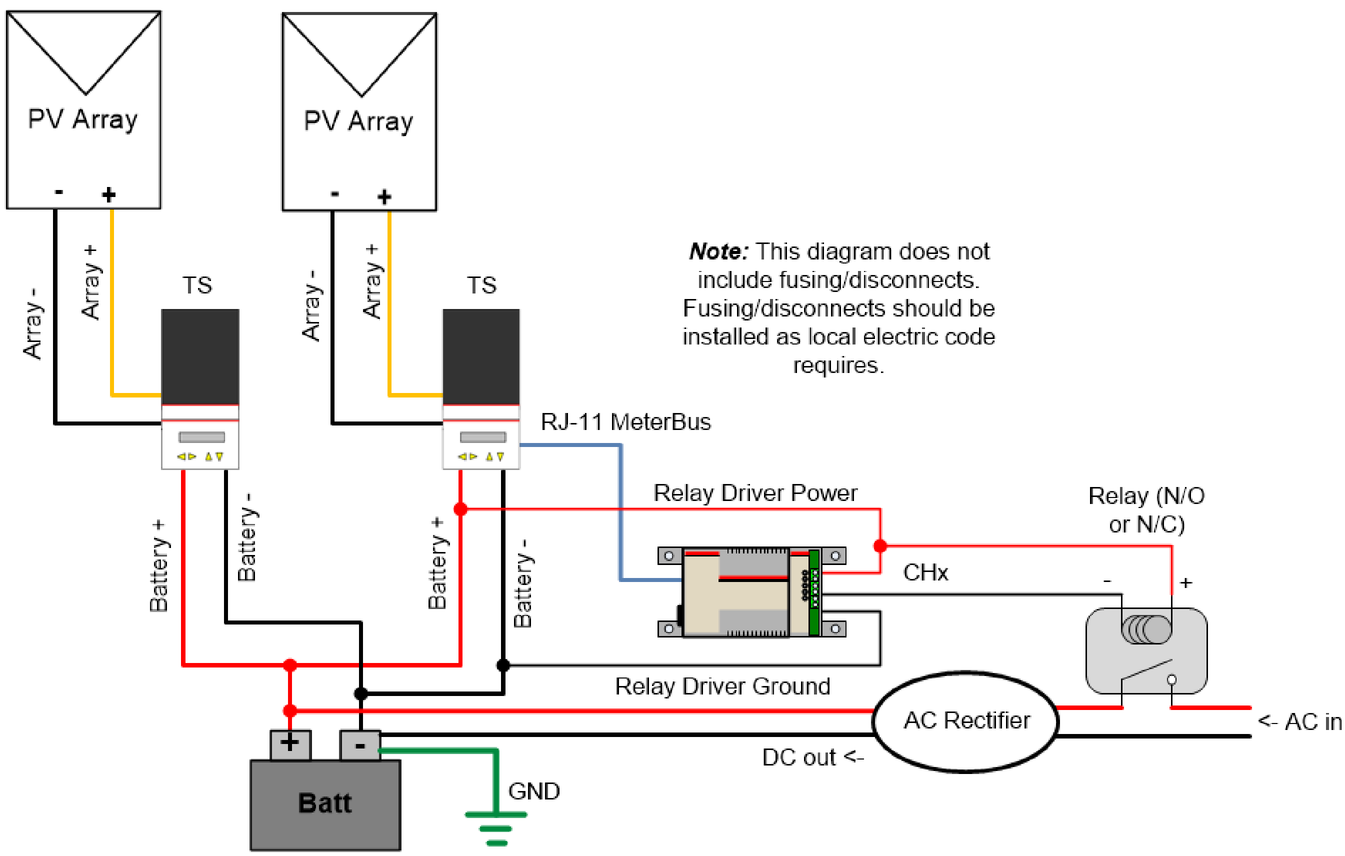
Systems that include a rectifier with full charging settings are often used with utility backup and off-grid systems. Float or rest voltages are only going to prevent the battery from getting discharged rather than recharge the battery. Many utility backup systems need to recover quickly after an outage and can’t wait for the sun to recharge the battery bank which can take several days when the weather is not cooperative. These rectifiers will start a bulk/ absorption charge cycle after an outage to fully recharge the battery and then will drop into float until there is another outage. On the other hand, off-grid generator system with solar may be set up to periodically run longer in order to fully recharge the battery if solar is not able to after several days of autonomy.

Generally speaking, setting the solar controller up with slightly higher voltage setpoints can help keep the solar priority working. It might also be possible to set the rectifier up with a shorter Absorption time than the solar Absorption time settings.

Some systems also include automation equipment such as programmable logic controllers (PLC’s) for advanced system control. It is also possible to incorporate battery monitoring equipment data or read MODBUS data from the solar controller in order to better control the generator and/or rectifier equipment.

Further, digital control over Morningstar products can be implemented with MODBUS write commands. For more information about this see our tech doc about how this can be achieved.

Real Time Control of Morningstar Products using Open Protocol MODBUS
Morningstar's Relay Driver is an automation product that includes 4 signal channels which can be used to activate relays. It can be connected to relay switches that can be used to enable and disable the rectifier and/or generator. The advantage of using Morningstar's Relay Driver is that it can operate in stand alone mode or in response to operational data from a Morningstar controller. Threshold settings can be set to activate based on battery voltage, array voltage, battery charge current and other parameters. It also has gen start settings that can be used with a generator. For more information about how to use the Relay Driver with different applications please see the Relay Driver Overview and Applications Tech Doc.



Example of Relay Driver for enabling/disabling AC Rectifier

Benefits of adding solar to AC Rectifier systems
Rectifiers are used extensively with DC micro-grid storage systems. This includes both utility UPS backup systems and off-grid generator systems. Including solar power for these systems with Morningstar controllers reduces the dependency on utility, generator and battery bank power usage. System configuration and settings can greatly influence how much a solar PV array energy can be utilized instead of rectifier energy. The type of DC micro-grid storage system can influence how much LCOE savings can be achieved with solar.

Advantages with Utility backup systems

- The cost of using utility power with rectifiers will vary depending on electricity rates.
- It is possible to rely on solar power when it is available during the day and create coordinated settings that can utilize more energy when solar power is not available from the battery bank.
- The solar PV will also operate independently so there will be less grid energy usage following a power outage.
- The battery bank may not need to be sized as large to make up for extended utility outages.
- Reduced battery usage during an outage means there will be fewer cycles so the battery bank can last longer.
- If a generator is used in the system it will not have to run as often which will save costs on fuel and generator maintenance.

Advantages with Off-Grid Generator systems

- The cost of can be significant. This includes fuel, maintenance, and equipment replacement.
- A high percentage of the solar PV array can offset the energy burden placed on the generator.
- Reduced fuel usage/costs significantly.
- More solar energy can be harvested than for utility systems. Unlike a grid connected UPS system where the grid maintains a high charge state the solar power will be used much more for recharging the battery rather than just powering the loads.
- Heavier generator usage results in more maintenance and shorter life expectancy for the generator.
- Fewer visits to site for refueling and generator maintenance is costly and time consuming in remote locations.

These benefits should be considered in relation to the added cost of integrating solar PV into the system to determine the LCOE. Besides the cost savings the system will typically be more reliable in addition to taking advantage of using clean energy with less generator noise.