Diversion Manual (Section 6.0):

31 March 03

The TriStar's third mode of operation is diversion load battery charge control. As the battery becomes fully charged, the TriStar will divert excess current from the battery to a dedicated diversion load. This diversion load must be large enough to absorb all the excess energy, but not too large to cause a controller overload condition.

6.1 Diversion Charge Control

In the diversion mode, the TriStar will use PWM charging regulation to divert excess current to an external load. As the battery becomes fully charged, the FET switches are closed for longer periods of time to direct more current to the diversion load.

As the battery charges, the diversion duty cycle will increase. When fully charged, all the source energy will flow into the diversion load if there are no other loads. The generating source is typically a wind or hydro generator. Some solar systems also use diversion to heat water rather than open the solar array and lose the energy.

The most important factor for successful diversion charge control is the correct sizing of the diversion load. If too large, the controller's protections may open the FET switches and stop diverting current from the battery. This condition can damage the battery.

If you are not confident and certain about the installation, a professional installation by your dealer is recommended.

6.2 Diversion Current Ratings

The maximum diversion load current capability for the two TriStar versions is 45 amps (TS-45) and 60 amps (TS-60). The diversion loads must be sized so that the peak load current cannot exceed these maximum ratings.

See section 6.4 below for selecting and sizing the diversion loads.

The maximum current input for all combined charging sources (wind, hydro, solar) must be equal or less than two-thirds of the controller's current rating. This limits the charging source input to the TriStar to a maximum of 30A (TS-45) and 40A (TS-60).

Limiting the total charging sources to 30A and 40A or less will provide a required margin for high winds and high water flow rates that might cause an overload and a safety disconnect in the TriStar controller. This would leave the battery charging unregulated.

CAUTION: If the TriStar's rating is exceeded and the controller disconnects the diversion load, Morningstar will not be responsible for any damage resulting to the system battery or other system components. Refer to Morningstar's Limited Warranty in Section 10.0.

6.3 Standard Diversion Battery Charging Programs

The TriStar provides 7 standard diversion charging algorithms (programs) that are selected with the DIP switches. An 8th algorithm can be used for custom setpoints using the PC software.

The table below summarizes the major parameters of the standard diversion battery charging algorithms. Note that all the voltages are for 12V systems (24V = 2X, 48V = 4X).

Standard Diversion Charging Programs
Table 6.3

All values are 25°C (77°F).

DIP Switches (4-5-6)	(A) PWM Absorption Voltage	(B) Float Voltage	(C) Time Until Float (hours)	(D) Equalization Voltage	(E) Time in Equal. (hours)	(F) Equalize Interval (days)	(G) Max. Equalize Cycle (hours)
off-off-off	13.7	13.5	3	14.0	3	28	3
off-off-on	13.9	13.7	3	14.2	3	28	3
off-on-off	14.1	13.9	4	14.4	3	28	4
off-on-on	14.3	14.1	4	14.6	4	28	4
on-off-off	14.5	14.3	4	14.8	4	28	5
on-off-on	14.7	14.5	4	15.0	4	28	5
on-on-off	14.9	14.7	4	15.2	4	28	5
on-on-on	**	**	**	**	**	**	**

(A) PWM Voltage - This is the PWM Absorption stage with constant voltage charging. The "PWM voltage" is the maximum battery voltage that will be held constant. As the battery becomes more charged, the charging current tapers down until the battery is fully charged.

(B) Float Voltage - When the battery is fully charged, the charging voltage will be reduced by 0.2 volts for all diversion settings. The float voltage and transition values are adjustable with the PC software.

(C) Time Until Float - This is the cumulative time in PWM before the battery voltage is reduced to the float voltage. If loads are present during the PWM absorption, the time to transition into float will be extended.

(D) Equalization Voltage - During an equalization cycle, the charging voltage will be held constant at this voltage.

(E) Time in Equalization - Charging at the selected equalization voltage will continue for this number of hours.

(F) Equalization Interval - Equalizations are typically done once a month. The cycles are 28 days so the equalization will begin on the same day of the week. Each new cycle will be reset as the equalization starts so that a 28 day period will be maintained.

(G) Maximum Equalization Cycle - If the battery voltage cannot reach the equalization voltage, the equalization will terminate after this number of hours to avoid over gassing or heating the battery. If the battery requires more time in equalization, the manual pushbutton can be used to continue for one or more additional equalization cycles.

6.3.1 Battery Charging References

The diversion load battery charging is similar to conventional solar charging. Refer to the following sections in this manual for additional battery charging information.

4.1 Four stages of charging (applies to diversion)
4.3 Temperature Effects and Battery Voltage Sense
4.4 Equalization
4.5 Float
9.0 Battery Information

6.4 Selecting the Diversion Load

It is critical that the diversion load be sized correctly. If the load is too small, it cannot divert enough power from the source (wind, hydro, etc). The battery will continue charging and could be overcharged.

If the diversion load is too large, it will draw more current than the rating of the TriStar. The controller's overload protection may disconnect the diversion load, and this will result in all of the source current going to the battery.

CAUTION: The diversion load must be able to absorb the full power output of the source, but the load must never exceed the current rating of the TriStar controller. Otherwise, the battery can be overcharged and damaged.

6.4.1 Suitable Loads for Diversion

Water heating elements are commonly used for diversion load systems. These heating elements are reliable and widely available. Heating elements are also easy to replace, and the ratings are stable.

NOTE: Do not use light bulbs, motors, or other electrical devices for diversion loads. These loads will fail or cause the TriStar to disconnect the load. Only heating elements should be used.

Water heating elements are typically 120 volts. Elements rated for 12, 24 and 48 volts are also available, but more difficult to source. The derating for 120 volt heating elements is discussed in 6.4.3 below.

6.4.2 Definition of Terms

Maximum Source Current:
This is the maximum current output of all the energy sources (hydro, wind, solar, etc.) added together. This current will be diverted through the TriStar to the diversion load.

Maximum Battery Voltage:
This maximum voltage is the PWM regulation voltage selected with the DIP switches, plus the increase with an equalization, plus the increase due to lower temperatures. The highest battery voltage is commonly 15, 30 and 60 volts for 12-, 24- and 48-volt systems.

Peak Load Current:
At the maximum battery voltage, this is the current the diversion load will draw. This peak load current must not exceed the TriStar's rating.

NOTE: Because the battery can supply any size load, the peak load current is not limited by the source (hydro or wind rating). The diversion load's power rating is the critical specification for reliable battery charging.

6.4.3 Load Power Ratings

The power rating of the diversion load will depend on the voltage of the battery being charged. If the heating element is not rated for the same voltage as the diversion system, the power rating of the load must be adjusted to the diversion system's voltage.

The manufacturers typically rate the heating elements for power at a specified voltage. The peak load current at the load's rated voltage will be the power divided by the rated voltage ($I = P / V$). For example: $I = 2000W / 120V = 16.7$ amps of current.

If the load is being used at a voltage less than the load's rated voltage, the power can be calculated by the ratio of the voltages squared. For example, a 120 volt 1000 watt heating element being used at 60 volts:

$$1000W \times (60/120)^2 = 250 \text{ watts}$$

The 1000W element will only dissipate 250W when being used at 60 volts.

NOTE: The loads (heating elements) can be used at the manufacturer's voltage rating, or at a lower voltage. Do not use the load at a higher voltage than the load's rating.

6.4.4 Maximum Diversion Load

The diversion load should never exceed the TriStar's current rating (45A or 60A). Note that the load is not limited by the source (wind, hydro), and will draw its rated current from the battery.

The following table specifies the absolute maximum diversion loads that can be used with each TriStar version. These loads (heating elements) are rated for the same voltage as the system voltage.

Nominal Voltage	TriStar-45	TriStar-60
48V	2700W at 60V	3600W at 60V
24V	1350W at 30V	1800W at 30V
12V	675W at 15V	900W at 15V

If the heating element is rated for a voltage higher than the system voltage, the current into the load will be reduced as indicated in the following table. A standard 2,000 watt / 120 Vac heating element is used as the reference.

Voltage	Power	Current
120V	2000 W	16.7 A
60V (48V nominal)	500 W	8.3 A
30V (24V nominal)	125 W	4.2 A
15V (12V nominal)	31 W	2.1 A

In a system with a 48 volt battery, it is necessary to parallel 4 heating elements to match the 2,000 watt capability of a single element rated for 120 volts. A 24 volt battery requires 16 heating elements in parallel to equal the 2,000 watt, 120 volt load.

6.4.5 Minimum Diversion Load

The diversion load must be large enough to divert all the current produced by the source (wind, hydro, etc.). This value is the maximum battery voltage times the maximum source current.

For example, if a hydro source can generate up to 30 amps of current in a nominal 48 volt system (60V maximum), the minimum diversion load size = 60V x 30A = 1,800 watts (rated for 60 volts).

6.4.6 General Sizing Example

Consider a 24V system with a wind turbine that is rated to generate 35A of current. A TriStar-45 will not provide the 150% diversion load margin, and the TS-45 is only rated for 30A of source input. The TS-45 will not provide enough margin for wind gusts and overloads, so a TS-60 should be used.

The diversion load should be sized for 52.5A (150% of the source current) up to 60A (the rating of the TriStar-60). If 55A is selected for the diversion load, the load must be capable of diverting 55A at 30V (maximum battery voltage). If a 30V heating element is used, it would be rated for 1,650 watts (or from 1,575W to 1,800W per the load range noted above).

If a 2,000 watt / 120 volt heating element is used, 13 of these elements in parallel will be required for the diversion load (4.2 amps per element [Table in 6.4.4] x 13 = 54.6 amps).

The minimum diversion load would be the source output (35A) times the voltage (30V). This would require a 1,050 watt heating element rated at 30 volts. Or if a 2,000W heater element rated for 120 volts is used, 9 heater elements will be required to draw the required minimum diversion load at 30 volts.

6.5 NEC Requirements

To comply with NEC 690.72 (B), the following requirements will apply when the TriStar is being used as a diversion charge controller in a photovoltaic system.

6.5.1 Second Independent Means

If the TriStar is the only means of regulating the battery charging in a diversion charging mode, then a second independent means to prevent overcharging the battery must be added to the system. The second means can be another TriStar, or a different means of regulating the charging.

6.5.2 150 Percent Rating

The current rating of the diversion load must be at least 150% of the TriStar source current rating. Refer to Section 6.2 (Diversion Current Rating). The maximum allowable current ratings for both TriStar versions are summarized below:

	Max. Input Current	Max. Diversion Load Rating
TS-45	30 A	45 A
TS-60	40 A	60 A

CAUTION: The NEC requirement that the diversion load must be sized at least 150% of the controller rating does **NOT** mean the diversion load can exceed the maximum current rating of the TriStar. **NEVER** size a diversion load that can draw more than the 45 amps or 60 amps maximum rating of the TriStar controllers.

6.6 Additional Information

Visit Morningstar's website (www.morningstarcorp.com) for additional diversion charge control information. The website provides expanded technical support for more complex diversion load systems.