Introduction

This document explains the procedures to use TCS MPPT converters correctly. Maximum Power Point Tracking (MPPT) converters interface an electricity source, e.g., a thermoelectric generator (TEG), to an electrical load. They perform two main tasks:

- Conversion of electrical voltage from that produced by the source to that required by the load
- Selection of the optimum electrical operation point at the source, to maximise its electricity production

Electrical Voltage Conversion

The electrical power available from the source is at any time limited. In thermoelectric systems it depends on the temperature difference available across the TEG devices; in solar photovoltaic (PV) systems it depends on the current solar irradiation level. As such, the electrical load power requirement should never exceed the maximum available power (Pmax). When this occurs the load voltage (Vload) typically sags to reduce the output power and the electrical load might not function correctly.

When the electrical load requires less power than Pmax the source actually generates less power than it could, thus working away from its maximum capability hence in this condition its power generating potential is not fully exploited.

To better explain these situations, consider the figure below, where the two blue straight lines represent the voltage versus current (V-I) characteristic of a TEG at temperature differences of 100°C and 200°C. The two red curves represent the electrical power generated versus current. The TEG at 100°C would not be able to power a load requiring 7V. The TEG at 200°C would be able to but would generate around 7W and not Pmax around 9.5W.

It is also fundamental to note that most electrical loads require a constant operational voltage but varying levels of electrical current. As such, this type of loads cannot be directly connected to a thermoelectric generator because at any moment it can operate only at single voltage-current level which is not practical.
The use of a dc-dc converter solves the problem of voltage regulation so that even the first TEG could be used to power a 7V. However, a standard dc-dc converter does not address the issue of full exploitation of the power available from the source and that of period surges in power requirements from the load. Both are solved using a MPPT converter with energy storage.

**MPPT converter with Battery Storage**

The battery connected to the output of the MPPT converter is an electricity storage that is charged with the difference between the electrical power required by the load and Pmax. E.g., looking at the graph above for $\Delta T = 200^\circ$C, if the load required 7W the extra 2.5W would end up in the battery.

The battery should be sized properly to the power rating of the TEG system, i.e. its capacity shall be high enough to bear the maximum available current from the TEG, at the battery voltage level. E.g., a lead acid battery with capacity XX Ah can be charged with a maximum current of XX/4 A. In the example above if Pmax is 9.5W and the battery at 12V, the capacity of the battery should be greater than 3.2 Ah.
When testing your TEG system it is sometimes easier to replace your intended final electrical load with an electronic load unit so that you can decide the current or resistance setpoint. You need to ensure that if the source can generate more power than the battery can sink, then the load can absorb the difference. E.g., if the TEG generates 100W and you have a 12V 20Ah battery then the load should be set in current mode at more than 3.33 A.

\[ I_{load} = \frac{100}{12} - \frac{20}{4} \]

The battery acts as an “infinite” current sink and its terminal voltage (correspondent to the MPPT converter’s output) cannot change instantaneously. Hence, the MPPT converter can vary the voltage at its input (corresponding to the source voltage). The MPPT converter is controlled by a MPPT algorithm that searches for the optimum source electrical operating point. In the above graph, the MPPT would operate the 100°C TEG at 2.1 V and the other TEG at 5 V. In high power solar panel installations the PV panels are usually not connected to batteries but to the AC grid using MPPT inverters (that convert the DC voltage from the source to AC voltage). The mains grid acts as an infinite current sink, hence its function is similar to that of a battery. However, if the AC grid is disconnected the inverter cannot operate the source at maximum power. For this reason it is common to add a battery stage to guarantee operation during grid black-outs.

TCS MPPT converters are used to maximise the energy generated by thermoelectric or solar sources and transfer it to 12V or 24V batteries. An inverter stage can then be used to power AC loads and/or to connect to the electricity AC grid. Contact us for more information.

**MPPT converter with power supply and electronic load at the output**

While testing your TEG system it is convenient to substitute the battery with a power supply unit (PSU) in parallel with an electronic load (EL). The PSU emulates the battery voltage and operates in voltage mode. The EL should be set in constant current (CC) mode. Typical PSUs do not sink current hence care should be taken while selecting the voltage/current limits for the two devices, depending on the maximum power that can be generated by the TEG, Pmax. The PSU voltage (Vpsu) corresponds to the battery voltage, hence 13V is a common setting for a 12V lead-acid battery. The EL current should be:

\[ I_{EL} > \frac{P_{max}}{V_{psu}} \]

Finally, the PSU current should be greater than IEL. When the TEG does not generate power the PSU powers the EL. When the source starts generating power, the PSU current progressively decreases because the MPPT converter provides the rest.
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