instead of ideal matching! Besides this fact, it should be considered whether the additional energy gained by optimum matching is relevant to the function of the system at all. For example, the battery in a typical Solar Home System will be fully charged before noon and the excess solar energy will be dissipated.

In general, caution is indicated if the inventors or the manufacturers claim a tremendous energy gain by the use of MPP trackers!

Nevertheless, there are three advantages in using charge controllers with matching DC/DC converters:

- In the case of long wires from the PV generator to the battery, the generator voltage can be chosen much higher than the battery voltage, resulting in lower currents and therefore lower wiring losses.
- In small applications, the PV module can consist of only a few, large cells instead of numerous small cells connected in series. This reduces production costs, the impact of cell mismatch and the sensitivity to partial shading.
- More complex charging-current profiles can be realised by means of a DC/DC converter.

19.1.1.6 Deep-discharge protection

To achieve a maximum service life, deep discharging of batteries as well as prolonged periods with a low state of charge should be avoided. Therefore, the load has to be disconnected automatically from the battery as soon as the state of charge falls below a certain level. The load should be reconnected to the battery only when a sufficient state of charge has been reached.

Different criteria for detecting the deep-discharge condition have been explained in Chapter 18. In commercial products, the battery voltage will be used as a criterion for load disconnection. As soon as the battery voltage drops below a determined level, the load will be disconnected via a (bi-polar) relay or a semiconductor switch. Also, a control signal can be output to shut down balance-of-system components like inverters.

More complex charge controllers are able to generate a warning signal when the deep-discharge condition is being approached. Also, different loads can be disconnected according to a given priority. Charge controllers including an energy-management systems (EMS) are used to start back-up generators such as diesel or gas generators, depending on the battery's instantaneous state of charge. Additional parameters like load demand, weather conditions and so on can be considered.

There should be an appropriate delay time $t_{\mathrm{d\ off}}$ of 10 to 60 s between the undershooting of the end-of-discharge level and the actual disconnection of the load as shown in Figure 19.9. This ensures that undesirable disconnection of loads with large starting currents, for example, motors, refrigerators, washing machines and so on can be avoided. As the end-of-discharge voltage threshold depends on the instantaneous battery current, some advanced charge controllers offer a current-dependent adaptation of the disconnect threshold.

The ideal solution would be deep-discharge protection based on the actual state of charge of the battery. As systems or algorithms for accurately measuring the state of charge