Figure 19.9   Changes in the battery voltage and load current during discharge

under the complex boundary conditions in PV systems are still under development, this type of controller is not yet in the market. For safety reasons, deep-discharge protection systems based on algorithms should be combined with a redundant control system based on simple voltage thresholds as described above!

The voltage threshold for reconnection of the load must be adjusted properly. If it is too low, the battery's open-circuit voltage will overshoot the threshold and the load will be reconnected periodically. In spite of the protection system, the battery will be deeply discharged and damaged. A time delay $t_{d\ on}$ as described above is also appropriate for guaranteeing a minimum state of charge before load reconnection.

In contrast to the end-of-charge threshold, the end-of-discharge threshold should not be temperature-compensated.

19.1.1.7 Monitoring systems and interfaces

Successful functioning of most PV systems strongly depends on the co-operation of the user. Reliable and meaningful information to the user about the current status of the system – the battery in particular – is therefore crucial. It would be ideal to have a "fuel gauge" that enables the system operator to plan the future energy demand. Such systems to monitor the state of charge have been discussed in Chapter 18.

As a minimum, the charge controller should be equipped with a display, for example, a light-emitting diode (LED) that indicates the conditions "Battery can be further discharged (green)" and "Battery is fully discharged (red)". Other conditions like "Battery close to end-of-discharge" can be helpful. Furthermore, an experienced operator can draw a lot of information from a meter showing the battery's voltage and current as shown in Figure 19.10.

All user interfaces should be ergonomic and provide only that information really required by the operator.

Energy-management systems are equipped with (potential free) inputs and outputs to communicate with external components, for example, to remotely start a diesel generator. In addition, standard interfaces such as RS 232, RS 485 or CAN-Bus can be integrated