un-interruptible power supplies and grid back-up systems, each individual cell in the series connection behaves differently. This individualisation results from differences in cell capacity, self-discharge rate, charging factor and so on. They are determined by production conditions, ageing and temperature and cannot be avoided on principle.

Conventional charge controllers are not able to recognise this variation in the behaviour of the cells, so that the undesirable operating conditions listed above arise. In practice, it is evident that the “weakest link in the chain” determines the quality of the whole string, and that the deviating performance of a single cell can lead to a chain reaction.

The problem of increasing divergence in individual cell properties within a battery has been known since the beginning of battery technology, so that over the years a number of different procedures to solve the problem have been developed. Most of them are based on the dissipation of the surplus energy of fully charged cells in a bypass element. This approach is not suitable for applications in which highest efficiency is crucial, such as PV systems. Furthermore, it is effective only with a fully charged battery – it has no impact when the battery is being discharged.

On the basis of experience with numerous PV systems, active, non-dissipative charge-equalising systems have been developed. In contrast to conventional dissipative systems, here the surplus energy from cells having a higher state of charge is redistributed among the remaining cells. As indicated in Figure 19.11, this redistribution occurs not only during or at the end of charging but also constantly during discharging.

As a result, cells with a lower capacity are supported by the other cells during discharge. Their relative state of charge decreases evenly with that of the cells with higher capacity. In this way, the entire available capacity of all cells can be used. During charging, some of the charging current is redistributed from weaker cells to stronger ones, so that these are charged with a higher current, resulting in faster charging.

The energy redistribution also allows cells with larger capacity tolerances to be connected together in series. Costly selection of matched cells during battery construction can thus be avoided. In extreme cases, it is even possible to sustain operation with a mixture of new cells and old cells after the replacement of defective cells. Additionally,

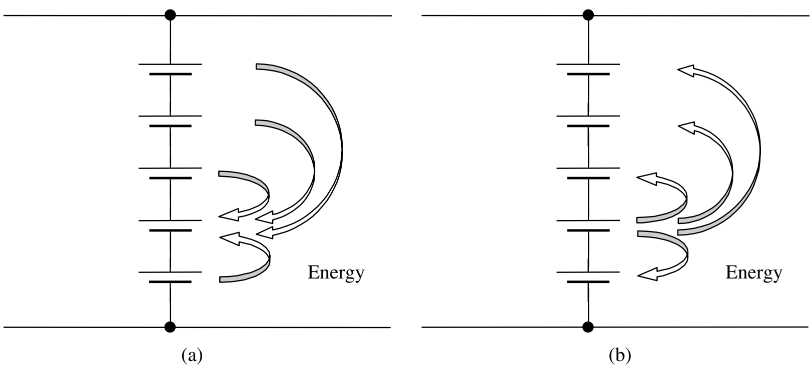

Figure 19.11 (a) Support for a weak cell during discharge by redistribution of energy from stronger cells. (b) Protection against overcharging