discharged. For example: $C_{10} = 10\text{ h} \times I_{10}$, or $C_{10} = 100$ Ah, $I_{10} = 10\text{ A} = 0.1 \times C_{10}$. Note that $1 \times I_{10}$ is not equivalent to $10 \times I_{100}$ as the C_{100} capacity is typically larger than the C_{10} capacity. For a more detailed example, see Section 18.4.7.3.

The *end-of-charge voltage* defines an upper voltage limit. Charging of the battery usually is not stopped on reaching the end-of-charge voltage (other than the end-of-discharge voltage), but the charge current is reduced accordingly to maintain the end-of-charge voltage over time.

The *lifetime* of a battery depends very much on the operating conditions and the control strategy. Manufacturers usually define two types of lifetime: the *float lifetime* (calendar lifetime) gives the lifetime under constant charging conditions without cycling (typical applications are uninterruptible power supplies), and for continuous cycling (*cycle lifetime*, typical applications are fork-lift trucks). Sometimes, the *shelf lifetime* is given. It defines the time for which a battery can be stored before usage.

Self-discharge describes the (reversible) loss of capacity on open-circuit conditions. It depends very much on the temperature.

The *state of health* is defined as the ratio of the actual measured capacity and the rated or nominal capacity. The state of health indicates to which extent the battery is still able to fulfil the requirements. According to the norms, lead acid batteries are at the end of their lifetime if the state of health is under 80%. However batteries can be operated significantly longer, but the days of autonomy are reduced accordingly and a system might not fulfill the energy requirements any more in a proper way. Batteries operating at a state of health of 50% are found frequently especially in hybrid systems. As a consequence, the share of the motor generator is increasing.

18.2.4 Definitions of Capacity and State of Charge

For operation and energy management in autonomous power supply systems, the battery capacity and the actual state of charge of the battery are the most important parameters. State-of-charge determination is difficult in autonomous energy supply systems with renewable energies because full charging of the battery as it is done frequently with conventional battery chargers is very unusual.

If state of charge is displayed, the question that arises is, what is the meaning of the specific values. Figure 18.3 shows different definitions of the battery capacity and the corresponding definitions of state of charge. The measured capacity of a battery might be smaller or even higher than the rated capacity given by the manufacturer. During the lifetime, the measured capacity decreases more and more due to ageing effects. The practical capacity is less than the measured capacity. Owing to the special conditions of renewable energy sources, batteries are almost never completely recharged (number of charging hours is limited) [4]. The maximum state of charge that is reached during normal system operation is called a "solar-full state of charge". Further on, the system defines an end-of-discharge criterion to avoid deep discharging of the battery and therefore accelerated ageing, which usually differs from the end-of-discharge criteria used for capacity tests. Therefore, the practical battery capacity is lower than the measured capacity. In the literature and other publications, no common definition of the state of charge is used. Therefore, any data and results must be handled with care.