A common configuration, called *polar tracking*, is when the axis is inclined just to the latitude. Then, the rotation axis is parallel to the rotation axis of the Earth, and the equations (20.54 and 20.55) become reduced to $\psi_{NS} = \omega$, and $\theta_S = \delta$. Because of the variation of the declination during the year, the cosines of the solar incident angle ranges between 0.92 and 1, having an annual mean value of about 0.95. This way, the polar tracker also collects about 95% of the energy corresponding to the two-axes case (column 7 divided by column 4 of Table 20.5). It is interesting to note that a polar tracker turns just at the same angular speed as that of a standard clock.

Another common configuration is when the axis is just horizontal. Horizontal one-axis trackers are of particularly simple construction and do not cast shadows in the N–S direction. This encompasses significant radiation reduction when compared with two-axis tracking (column 6 divided by column 4 of Table 20.5), but still significant radiation increase when compared with optimally tilted fixed surfaces (column 6 divided by column 8 of Table 20.5). Because of this, they are today the most common tracking solution in large PV plants: PVUSA [45], Toledo [39] and so on. And the same is true for solar thermal plants. We should remember that the very first solar tracker used in any significant way for power generation was just a N–S-oriented horizontal one-axis tracker associated to a parabolic reflecting trough, constructed in 1912 by Frank Shumann and C.V. Boys to power a 45-kW steam-pumping plant in Meadi, Egypt [46]. The tracking surface covered an area of 1200 m^2. The plant was a technical success, that is, reliable trackers existed already at the time, but it was shut down in 1915 due to the onset of World War I and cheaper fuel prices. The world's largest solar plant, at the well-known Luz solar field, erected in California from 1984 to 1986, also employs this type of tracking and, again, with great technical success [47]. The surface position and the solar incident angle are given by

$$\beta = \arctan \left| \frac{\sin \psi_S}{\tan \gamma_S} \right| \tag{20.56}$$

and

$$\cos \theta_S = \cos \delta \cdot [\sin^2 \omega + (\cos \phi \cos \omega + \tan \delta \sin \phi)^2]^{1/2} \tag{20.57}$$

Finally, it is worth commenting that large PV generators have several rows of modules mounted above the ground. The distance between rows affects the energy produced by the PV generator. If the separation is increased, fewer shadows are cast by some rows on the others and more energy is produced. But it also affects the cost, as greater separations lead to more land being occupied, longer cables and more expensive civil works. Therefore, there is an optimum separation, giving the best trade-off between greater energy and lower cost. There is a widely held view that tracking generally requires much more land than static arrangements. However, it should be outlined that this is not necessarily the case when horizontal one-axis tracking is concerned. The interested reader is encouraged to refer to [48], which deals in detail with tracking and shadowing in large PV arrays.

20.9.3 Concentrators

PV concentrators are able to capture only direct-beam solar radiation and require tracking mechanisms to keep in focus the solar cells. Therefore, they are best suited to sunny