European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'10)
Granada (Spain), 23th to 25th March, 2010

New solar angles and their corresponding tracking systems efficiency

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The most significant parameter to evaluate the performance of a PV tracking system is the absolute *direct tracking efficiency*, representing the ratio between the energy of the direct solar radiation that falls normally on a PV surface and the energy of the available direct solar radiation [1, 2]; a biaxial PV tracker is usually efficient if its *direct tracking efficiency* is over 97%.
The literature presents two terrestrial systems which are describing the solar ray orientation (see Fig.1): the equatorial system OXYZ (δ,ω) and the azimuth system $QX_0Y_0Z_0$ (α,ψ); from these angular pairs were derived the classic tracking open linkages [1, 2].

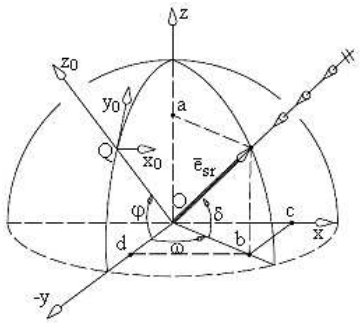

Fig.1 Equatorial system OXYZ (with the solar ray angles: hour angle ω and declination δ) and azimuth system $QX_0Y_0Z_0$ (with the solar ray angles: azimuth ψ and elevation α)

Instead of the classic angular pairs (δ, ω) and (α, ψ), the sun ray orientation can also be described by another two angular pairs: (ω1, δ1) and (ω2, δ2) in the equatorial system OXYZ and (ψ1, α1) and (ψ2, α2), in the azimuth system $QX_0Y_0Z_0$ [1, 2]; for each of them are proposed appropriate tracking open linkages.
The mathematic expressions for the new angles are established, by geometrical calculus, as opposed to the classical angles.
The real angular strokes for the six sunray angular pairs (for geographic region of Braşov, Romania) are established by simulating their mathematic expressions during the main, representative solar moments of the year: the spring/autumn equinox, the summer and winter solstice. The angular stroke of any solar angle is obtained as difference between the extreme values of the considered solar angle.
An hourly tracking program is simulated for each PV daily angular stroke, in two situations: a) when the PV daily angular stroke is equal to the homologous sunray stroke; b) when the PV daily angular stroke is smaller than the sunray stroke (the PV angles respect the notations of their homologues sunray angles, additionally marked with a star).
In order to determine the direct tracking efficiencies for each of the six tracking open linkages is required the modeling of the incidence angles and of the direct received radiation for each six configurations.

Table I. The initial and the most reduced daily strokes and their corresponding direct tracking efficiencies for each equatorial and azimuth type.

	Δω*	Δω1*	Δω2*	Δψ*	Δψ1*	Δψ2*
Complete	240°	180°	360°	240°	180°	180°
	Direct tracking efficiency [%]					
	98,5	99,2	98,6	98,4	98,5	98,6
Reduced	120°	120°	180°	150°	120°	120°
	Direct tracking efficiency [%]					
	98,5	98,5	98,6	98,2	98	98,5

A comparative analysis between the direct tracking efficiencies show that all tracking open linkages allow an important reduction of the daily angular stroke with a negligible reduction of the tracking efficiency.

References:

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