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Solar Energy Plants' Sun Tracking Systems' Experimental Results and Energy Calculation

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Abstract In the paper the sun tracking systems' usage for high-potential concentrators and solar PV to be directed to the sun have been studied due to the cographical location of Absheron peninsula.

Keywords Sun tracking system, Azimuth, Zenith, Solar energy plant, Solar PV

1. Introduction

According to the geographical coodinates, for the perpendicularity provision of the for high-potential concentrators to teh sun along the day we should take into considration ist action on azimuthal and zenithal surface:

In the paper diurnal sun rays' density has been determined on the concrete area. The direct sun rays S_{dir} amount falling on the surface under θ angle is to be defined [1, 2]:

$$S_{dir} = S_{r\max} \cdot K_{at} \cdot \cos\beta$$

Here, $S_{r\max}$ - solar radiation constant which equals the energy amount coming from the Sun to the Earth. $S_{r\max} = 925W/m^2$; K_{at} - correcness ratio being used for sun rays' passing through the atmosphere (air mass); β - falling angle of sun rays directly on the surface.

$$\cos\beta = \sinh_g \cos\alpha + \cosh_g \sin\alpha$$

Here, α - the angle of the solar PVs in comparison with horizon; h_g - the sun height angle within the exact time.

After these parameters motion trajectory can be calculated on the azimuthal surface of the concentrator [3].

Concentrator movement on the azimuthal surface has to be same with conspicuous sun angle speed. For this azimuthal motion velocity should be expressed as follws:

$$\omega_a = \frac{d_a}{d_t} = \frac{k\cos^2\delta(\sin\varphi - \cos kt \cdot tg\delta\cos\varphi)}{1-(\cos\varphi\cos\delta\cos kt + \sin\varphi\sin\delta)^2}$$

Here, kt - hour angle from midday;

δ - inclined angle of the sun;

φ - geographical parallel of the area.

Annually the greatest azimuthal motion rate occurs in June 21, the smallest one happens in December 21. For that, maximal azimuthal movement rate is to be defined as below:

$$\omega_{a_{maks}} = \frac{k}{\sin\varphi - 0,4338\cos\varphi}$$

The total power of the electric motor which makes the concentrators move on azimuthal surface must be determined like this:

$$N_{mot} = 0,0098\frac{\omega_{a\max}}{\eta}\sum_n^m\left[0,7G + (0,005G + \frac{\bar{S}\rho\upsilon^2F}{2})R\right]$$

Here, η - efficiency of whole mechanism having role in the guiding system;

m -quantity of the every part consisting of concentrators with pieces;

n - coun of the concentrators in each part with pieces;

G - weight of the concentrators kg;

ρ - air density kg/m^3;

υ - calculated wind speed $m/\sec$;

F - surface square of the concentrators m^2;

R - radius of the motion path on azimuthal surface m;

$\bar{S}$ - the measured ratio on the aerodynamic resistance of each concentrator and has to be determined as follows [4]:

$$\bar{S} = C_x\cos\psi - C_y\sin\psi + \mu(C_x\sin\psi + C_y\cos\psi)$$

Here, C_x və C_y - aerodynamic ratio;

μ - shaking coeffient during themovement;

The impact of the aerodynamic forces on the concentrator surface should be calculated as below [5, 6]:

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$$\beta = 90 - (\gamma + \frac{\alpha}{2})$$

Here, γ - angle between central axe of the concentrator and wind direction;

α - angle bewteen central axe of the concentrator and direction to the center.

Due to this calculation ψ is defined as below:

$$\psi = \beta - \frac{\alpha}{2}$$

According to the calculations carried out I should say that the force of demanded electric motor consists of 0,3% from the total energy during concentrator mvement on azimuthal surface.

The energy system possessing solar PVs may be used for the electric motor work. Thia's why averagely solar PV having 300 W power, 2 accumulators and a controller are necessary.

Provision of concentrators' movement on zenithal surface annually depends on days, months and the sun height due to the geographycal location, relief of the territory. Naturally the Sun height angle is able to be distingiushed in the mention area in the stationary point taking into considration the geographical location and territory relief. Identidfication of these angles is realized to the following formular [7-9]:

$$tg\vartheta = \frac{\sin\alpha\cos\theta}{\cos\alpha\cos\theta + \cosh}$$

$$tgz = \cos\vartheta \frac{\sinh\sin\theta}{\cos\alpha\cos\theta + \cosh}$$

Here, θ angle between sun ray reflected from the concentrator surface and the horizontal surface. Due to the realized calculation I dare say that the above mention parameters should be taken into considration for the concentrators to move on the both surfaces. But depending on geometrical shape of the concentrators (parabolic, parabolo trough, flat and others) it shoud be done. For egxample parabolo through concentrator can move on only zenital surface. For this 2 conditions must be followed. The first one is that the row of the parabolo through has to be horizontal on the length. The second condition is that the central axe of the concentrator is to be directed to the maximum sun height angle depending on the geographical parallel. In the second variant some mistakes appear that it influences negatively to the work regime of the concentrator. In order to calculate the deffects and determine the optimal showing the next equation is used:

$$\left.\begin{array}{l} \cos z_1 \cos\vartheta_1 \cos\mu + \sin z_1 \cos\nu + \cos z_1 \sin\vartheta_1 \cos\eta \\ = \cos\varphi \\ \cos z_2 \cos\vartheta_2 \cos\mu + \sin z_2 \cos\nu + \cos z_2 \sin\vartheta_2 \cos\eta \\ = \cos\varphi \\ \cos z_3 \cos\vartheta_3 \cos\mu + \sin z_3 \cos\nu + \cos z_3 \sin\vartheta_3 \cos\eta \\ = \cos\varphi \\ \cos^2\mu + \cos^2\nu + \cos^2\eta = 1 \end{array}\right\}$$

Here, I dare say that, movement of the concentrator aord its axe is to be realized by the transient angle rate. Therefore, ondulating angle speed can be determined as below [7]:

$$\frac{d\psi}{dt} = \frac{dz}{dt}\frac{\cos z}{\sqrt{\sin^2\varphi\sin^2\nu - (\sin z - \cos\varphi\cos\nu)^2}}$$

During the provision of rotation in the concentrator axe, number of gears $\frac{d\psi}{dt}$ of the mechanism depends on the maximal datum. Therefore, the general number of gears of the mechanism can be defined like this:

$$i = 0{,}1045\frac{n_{mot}}{(\frac{d\psi}{dt})_{\max}}$$

Here, n_{mot} - rotary speed of electric motor, rotation/sec.

After the current experiments [10] at the result of the calculation due to the above mentioned method in some territories summeries on azimuthal and zenithal surface angles of the solar concentrators while directing to the Sun and risk situation have been obtained. On the base of the experiments carried out in the southen-east and the suther-west parts of Absheron peninsula on the both surfaces dependence between surface angles and day time has been detected. At the next table rotational angle data on the both azimuthal and zenithal surfaces of the solar concentrators were given for summer in the territry of the southen-east and the southen-west parts of Absheron peninsula.

Table 1. The experimental data carried out in summer in the southen-east and the southen-west parts of Absheron peninsula were presented

	The Southen-East											
Houres	8^{00}	8^{30}	9^{00}	9^{30}	10^{00}	10^{30}	11^{00}	11^{30}	12^{00}	12^{30}	13^{00}	13^{30}
Azimuthal angle	79.2	72.6	65.1	57.3	50.1	42.4	34.3	26.6	19.9	12.5	5.2	+2.4
Zenithal angle	82.2	75.4	68.6	61.2	53.8	46.4	39.6	32.4	25.4	18.6	12.5	8
	The Southen – West											
Houres	13^{30}	14^{00}	14^{30}	15^{00}	15^{30}	16^{00}	16^{30}	17^{00}	17^{30}	18^{00}	18^{30}	19^{00}
Azimuthal angle	2.4	9.8	17.1	24.5	31.9	39.6	46.6	53.9	61	68.8	76.4	84.2
Zenithal angle	8	12.5	18.6	25.4	32.4	39.6	46.4	53.8	61.2	68.6	75.4	82.2

At the table 1 azimuthal and zenithal angles data of the concentrators to be perpendicular to the Sun on the day hours in the southen-east and the southen-west parts of Absheron peninsula.

Thus, the experiments were realized by using ocular and actinometric tubes settled in two seperate surfaces under entirely 90^0 angle. According to the experiments after each 30 second data obtained on both surfaces and directions have been noted. The total measurements duration covers from 8^{00} am till 7^{00} pm by consisting of 11 hours in a day.

Table 2. Tha major parameters of solar PVs (U, V and I, mA) and daily indexes

Hours	Motion on azimuthal and zenithal surfaces		Stationary situation	
	U, V	I, mA	U, V	I, mA
8^{00}	21.10	96	8.87	48
8^{30}	21.22	158	10.63	99
9^{00}	21.74	221	12.08	196
9^{30}	21.68	248	14.12	212
10^{00}	22.34	261	16.58	233
10^{30}	22.58	281	17.01	259
11^{00}	22.84	324	17.26	311
11^{30}	23.18	384	18.35	376
12^{00}	23.54	418	20.41	401
12^{30}	23.36	435	21.18	429
13^{00}	24.77	464	22.13	446
13^{30}	26.20	488	24.90	465
14^{00}	25.91	471	23.39	451
14^{30}	23.65	438	22.51	423
15^{00}	22.98	409	21.36	389
15^{30}	23.05	388	20.79	328
16^{00}	22.51	356	18.36	248
16^{30}	21.35	324	17.04	205
17^{00}	21.01	301	16.23	164
17^{30}	18.62	271	14.31	131
18^{00}	15.11	256	12.20	99
18^{30}	12.32	192	10.88	74
19^{00}	10.58	101	8.21	51

The sun tracking system has been tested on the both surfaces for the obtained data correcness to be known. To the test results the reliability of the system functionality level was revealed. During the experiments by moving concentrators on both azimuthal and zenithal surfaces two same solar PVs parallelly were used to supply electricity of the motor make the system rotate. Due to the summery the changing indexes of the main energy parameters of solar PVs (U, V və I, mA) depending on the hours of the day were noted. The data got were given at table 2. Whilst the experiments 2 solar PVs made in Taiwana controller from Pro star-15 mark have been utilized. The solar PVs is in picture 1 and the controller is in picture 2.

Picture 1. Solar PVs, controller and accumulator

Picture 2. Controller from Prostar-15 mark

2. Results

Summerizing experimental results the following results have been revealed:

- Maximal energy efficiency state of the device;
- High energy potential and effectivness for the plant;
- Advisable areas of Absheron peninsula for the energy plant usage;
- Engine capacity of the electric motor;
- Suitable geographical location parameters for the test;
- Time (from... to) for the optimal work regime;
- Perpendicularity duration on the Sun;
- Necessity to the sun tracking system to get more power.

Indeed the experiments and tests give opportunity to develop the ways to obtain much more energy efficiency at the solar plants by using suntraking systems.

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