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Kite flow angle effects on Kite energy generation

N. Sabet , F. keynia , E. Assadian

Abstract— For electricity energy generation, Kite system, a system for conversion of up and down linear movement of Kite halter, such as attack angle, to a rotational movement of an axis, is used. We can generate electricity by axle attachment to a generator. An important point in energy generation by kite is the flow angle which can be obtained with respect to kite's width and height and its distance to the ground. Some argue that we can neglect this angle because of its low amount, but even this low amount has many effects on energy generation. We will show its importance in this article [3,5].

Keywords— Flow angle, Generator, Kite, Attack Angel

I. Introduction

Concerns about shortage of fossil fuels in recent decades, increased attentions to renewable energy resources. We believe that wind power is of one the useful renewable energies. Many notions and designs which are created for conversion of wind energy to electricity are presented. Nowadays is seems that most of the systems which are designed for electricity energy generation, are complicated and big in the size. Kite is pioneer in the evolution of the methods for clean energy generation from the wind, and its aim is to compete in wind industry, yet we use Kites against fossil fuels.Today with technology we can only turn the surface, in a few optimal points, in order to use massive wind energy. Wind turbines can't reach to high altitudes and they have many dimensional restrictions: Axles can hardly be in the height of 100 meters from the ground and the whole structure is heavier, more unstable and most importantly more costly[1.3] . Kite dynamic energy system has a potential which have a considerably lower cost and it doesn't need a huge tower in spite of wind turbines. Is this system since we don't need to use huge blades, noise and dangers which are imposed to nature and specially birds, are eliminated. Moreover negative effects of landscapes and natural attractions are cancelled. Kite power system can be used in regions which has great wind speed differences since we can use kite systems in higher altitudes. The advantage of reaching to higher altitudes is that in these altitudes, wind speed is more stable

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II. Kite and the importance of flow angle

Kite dynamic energy system has a potential which is considerable power than a wind turbine which needs a huge tower. Without huge blades which create noise and natural concerns, we can use kite systems. Aalso visual pollution concerns are eliminated and we don't have any kind of negative effects on landscapes and natural attractions. Kite power system can be implemented in regions which have great wind differences and high altitudes. Turbines can't reach higher altitudes and have many dimensional constraints: Axles can hardly be implemented in a 100 meter altitude and this structure is heavier, more unstable and more expensive [2,4].
In kite notion compared with wind turbine, which has its most Output in wing tips, wing and generator speeds can easily be transferred to the ground . This structure which includes the base, is less expensive and lighter. In addition, we can raise practical altitude with respect to wind conditions.
In designing and building of a kite, we have to consider these properties: stability, ease of use and durability. The advantage of a big kite, is linear tension in higher wind speed and more stability when it is at the highest point and the main reason of this advantage is kites large area. Smaller kites have the equivalent advantage, meaning that in lower wind speeds, we need only a gentle breeze to hold them in the air, although they have less stability because of their smaller coordinates. Energy generation importance of a kite depends on the change of attack angle[12,11,4].
In this article we simulate a kite with the length of 150 and width of 60 CM by Fluent software and put this kite in front of 7, 10 and 15 M/S and also we will use flow angles (0 and 3 degrees) to show the importance of this angle (the angle

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between two side of a kite for tension) in kite designing and simulation for energy generation.

We can calculate flow angle as below:

$$\frac{\frac{x}{2}}{y} = \sin \alpha \quad (1)$$

In which:

X= Longitudinal distance of two side of the kite

Y= The length of the cord or kite height relative to fixed part

a= kite flow angle

After we simulate the kite with Fluent which is powerful software for kite simulation in different speeds and with respect to the flow angle which is calculated as (1) , we can calculate kite tension force and then we can convert this force to winch moment by MATLAB. Since winch is coupled with generator axle, we can easily calculate need power.

Since our dimension are small, we can see that kite flow angle is negligible and near to zero. Even in kites with bigger dimensions, this angle is neglected and so there will be differences in further calculations and power generation . Here, after simulation and calculation of the useful power, we will show the importance of this angle [13,2,1].

For kite speed calculation, with respect to arm movement, we will use this formula:

$$Vk = \frac{R_a.\omega}{\cos(\gamma - \beta + \frac{\pi}{2})} \quad (2)$$

Here Ra is the length difference between kite halter and axis point, $\omega$is angular speed of arm rotation, $\gamma$is the angle between the arm and the ground. lift coefficient (CL) and drag coefficient (Cd) of a kite can be achieved by:

$$Cl = \frac{2.\pi.\alpha}{1 + \frac{2}{AR}} \quad (3)$$

$$Cd = Cdo + \frac{cl^2}{\pi.AR.eo} \quad (4)$$

With calculation of Cl and Cd, we can find a big range of stretching ratio :

$$\frac{L}{D} = \frac{Cl}{Cd} \quad (5)$$

With the calculation of stress line tension from steady state theory, we can express the below equation:

$$T_c = \frac{T2.\cos\left(\gamma-\theta+\frac{\pi}{2}\right).Ra+(gW\_DB.\cos(\gamma).\frac{R_d}{2}-gW\_BA.\cos(\gamma).\frac{R_a}{2}-W2.\cos(\gamma).R2.g)}{\cos(\gamma).R_c}=0 \quad (6)$$

With respect to calculated amounts for kite line tension, string tensions can be determined. Next step is to use these string tensions for the estimation of rotational moment and speed from a generator axis.

generator axis moment can be calculated as below:

$$T4 = Tc.r2 \quad (7)$$

III. the simulation of the dynamic part of the kite

Dynamic system simulation gives us a wider view for power generation and overall performance of the whole mechanism. this simulation allow us to observe system's operational properties in response to the time. Also we can calculate average amounts which are used for the determination of valuable information. the main advantage of this system compared to steady-state theory is that we can anticipate system performance. Tthe power is estimated by the equation below:

$$P = T.\omega \quad (8)$$

In which T is rotational kite moment and W is rotational speed of the rotating bar. with the replacement of angular speed, we can calculate the power:

$$P = T\frac{Va}{RA} \quad (9)$$

The final goal of the simulation is to anticipate kite movement and power generated by the mechanism. Two properties must be considered and examined: axial RPM and its moment. When we have the early estimation by the help of these amounts, then we may have to manipulate the simulation in order to find the most effective design of the system. From the most effective ones, we can anticipate final power capabilities for our mechanism. We do simulation based on steady-state simulation and dynamic model which has differential equations[9].

IV. Kite simulation

The final goal of the simulation, is the anticipation of kite movement and generated power by the mechanism. Two properties must be considered and examined: axial RPM and

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its moment. When we have the early estimation by the help of these amounts, then we may have to manipulate the simulation in order to find the most effective design of the system. Fluent Software can do the calculations with regular precision and Double Precision and the user can choose whichever he/she wants.This software is based on limited volume method which is a very powerful and suitable method for calculational fluid dynamics. Fluent is very popular because of its capabilities: permanent and non permanent, viscous and non viscous flow modeling, combustion, turbulent flow , motion of solid particles and liquid droplets and many other aspects which are functional in industry and research. Which the help of these methods , in addition to speedy numeral calculations, we can obtain more information with more details such as speed differences, pressure , temperature and so on. of course , most of the times, experimental simulations for obtaining these kind of information is complicated and time consuming and in some occasions this is completely impossible. In most of the fluid dynamic problems, with respect to the complexity of equations, we cannot use analytical solutions. for this purpose we have to use partial differential equations and such thing is obtainable only by numerical methods. our kite lattice (or networking) is unstructured and we have about a 1.5 million cells. after early solutions, for verification, we must analyze our network by Ansys Fluent. An important point is the Rope Angle in both sides of the kite (flow angle) which is considered with deterministic length and width and we use a 3degree angle in our simulation. Since this amount of angle is apparently negligible, so we will run our simulation for 0 and 3 degrees to show the importance of the angle in simulation and its effects on resultant tension force.

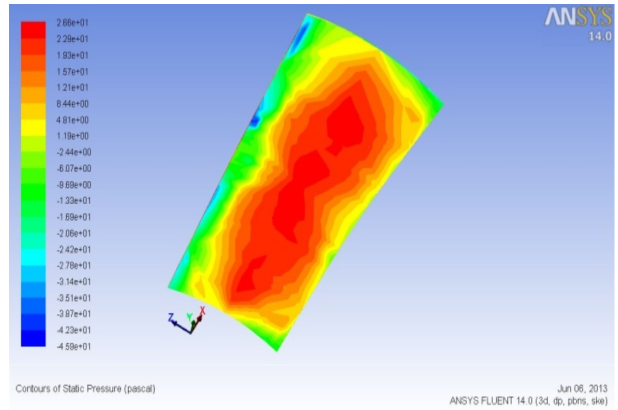

fig1 : pressure counter under 0 degree of flow angle, flux rate : 10m/s (for the lower part of the Kite)

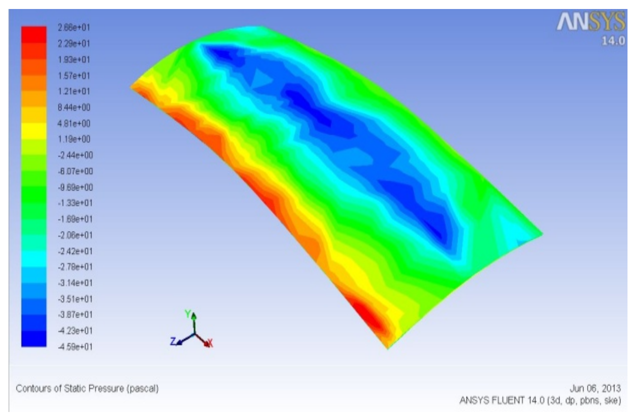

fig2 : pressure counter under 0 degree of flow angle, flux rate : 10m/s (for the upper part of the Kite)

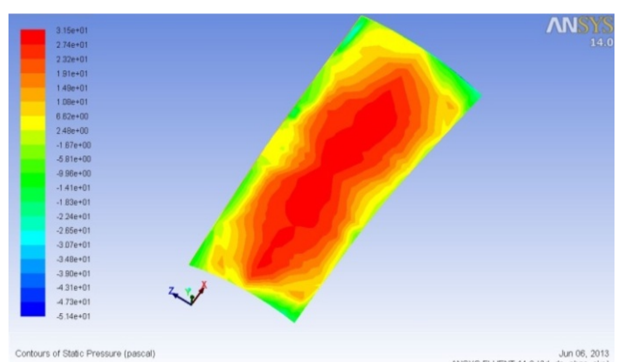

fig3 : pressure counter under 3 degree of flow angle, flux rate : 10m/s (for the lower part of the Kite)

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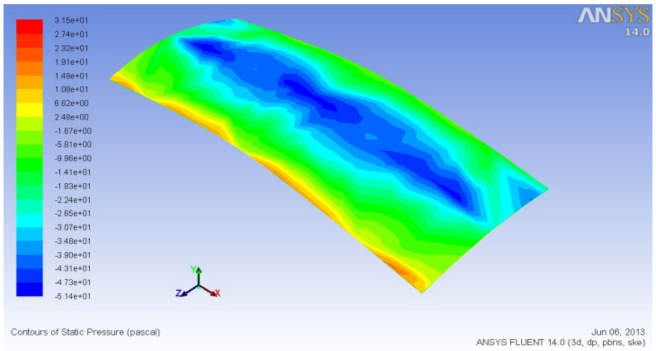

fig4 : pressure counter under 3 degree of flow angle, flux rate : 10m/s (for the upper part of the Kite)

V. simulation results

with respect to fig1-4 , we must say that red parts represent parts which have bigger air flow and blue color represents the most little pressures on the kite.
with respect to simulation and numerical equations, we can obtain kite tension force in different speeds and different angles and then we can convert these forces to moments (with MATLAB software and by winch) and then we can calculate productivity by motor.
numerical results are presented in table 1 :

Table 1.results of simulation

A era	α	speed	C l	Cd	L	D	L/D	F	ß	P_{mech}	P_{elec}
0.9	0	7	0.45517	0.06857	12.29471	1.852161	6.638034	12.4334	8.571363	0.3215	0.2493
0.9	0	10	0.45543	0.067844	25.10558	3.739901	6.71293	25.38261	8.477165	1.3428	1.0413
0.9	0	15	045706	0.067086	56.68972	6.813046	6.813046	57.2971	8.354328	6.9304	5.3729
0.9	3	7	0.64554	0.04604	17.43684	14.01946	14.01946	17.4811	4.082035	0.6359	0.4931
0.9	3	10	0.64647	0.045461	35.63666	14.22032	14.22032	35.7246	4.024567	2.6679	2.0688
0.9	3	15	064815	0.044907	80.39085	14.43316	14.43316	80.5835	3.965408	13.93955	10.7979

in above table :
a : kite angle with flow
Speed : flow speed
Cl: Lift force coefficient
Cd: drag force coefficient
L: total lift force
D : total drag force
L/D : is a criterion which shows lift force over a flying drag
F : resultant force over the rope
P mech : input power
P elec : output power of kite

VI. conclusion

We can see that 3 degrees can double the power , the power is reached to 10.79797 . This amount for a 10M^2 Kite is considerable and thus we must include this important parameter.

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