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RETRIEVING SOME OF THE ELECTRICAL ENERGY USED IN RUNNING POULTRY HOUSE VENT FANS IN LIGHTING

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ABSTRACT: New and renewable energies are applied in the field of poultry farming in order to reduce the increasing energy demand and to some extent provide potential alternative profits to producers. An innovative system is introduced to recover part of the energy from artificial wind sources (exhaust air systems). In this study, a preliminary system was studied to recover a portion of ventilation energy in poultry houses. A horizontal axis wind turbine (HAWT) is used at the ventilation fan outlet to recover energy with other electronic components. The preliminary study aimed to collect data on the performance of the suction fan and wind turbine in different scenarios and evaluate any negative impact on the ventilation system, especially static air pressure. The best position for the HWAT turbine, with a diameter of 1130 mm, is facing the ventilation fan, with an output diameter of 1380 mm, when the center of the turbine is at the center of the fan and a distance of 10 cm from the fan. In this configuration, the ventilation fan flow rate is improved by 0.23%, and the fan motor power consumption is reduced by 1.58% while the turbine generates 26.2 W.

Key words: Small Wind Turbine- Man Made Wind- Harness of Ventilation Airflow.

INTRODUCTION

Economic growth and energy demand are intertwined. Therefore, one of the most important concerns of the governments in the world is the need for energy security. Widespread and massive consumption of fossil fuels has led to rapid economic growth in advanced industrial countries but also increased carbon dioxide in the atmosphere and consequently caused global warming and climate change (Jean-Baptiste and Ducroux, 2003), which caused several disasters in the last few years, all over the world. Renewable energy sources should replace a part of fossil fuels fundamentally and structurally. Renewable energy sources are natural resources such as sunlight and heat, biomass, geothermal heat, hydropower and wind, which are naturally replenished. The Egyptian government has recognized the importance of renewable energy and is working to increase the electricity generated from renewable sources (Ibrahim, 2012). So, Egypt is going to increase the electricity generated from renewable sources to 20% by 2022 and 42% by 2035 (Salah *et al.*, 2022). Wind energy is considered the most hopeful and promising renewable energy source from the points of view of safety, simplicity, and quantity (high extracted energy). Cumulative population growth is increasing faster than food supply in all parts of the world. Therefore, modern technologies are being applied to overcome the limitations of food manufacturing. The air conditioning of agricultural buildings for horticulture, planting (green houses) and livestock plays an important role in increasing food production. The livestock and poultry building system is one of the applications that provides for the ability of high- density production and enables the manufacturers to solve productivity problems. Modern tunnel ventilation houses require numerous large fan systems to provide year-round ventilation and cool the poultry flocks in the summer (Frazier, 2017).

Thus, this research investigates the concept of a new clean energy recovery system. The proposed system was establishing a small commercially available wind turbine in front of a ventilation a fan in poultry house to generate electricity from the exhaust airflows. The

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objectives of this research can be presented as below:

1. To fabricate and establish a system of energy recovery wind turbine generators for integration with an exhaust air system.
2. To perform a series of tests, in the lab and field, on the established energy recovery system of the ventilation fan in a poultry house.

The main aim of the research is to prove that the wind power from an exhaust air system can be utilized for beneficial useful electrical energy. Moreover, the utilization of this man-made wind energy using this energy recovery system does not negatively effect on the performance of the exhaust air system (ventilation fans in poultry houses).

MATERIALS AND METHODS

The lab experiments were conducted in Agricultural and BioSystems Engineering Department, Faculty of Agriculture, Shebin El-kom, Menoufia University, Egypt. While the field experiments were carried out in a poultry farm in Denshawai village - Al Shuadaa center - Al Menoufia.

1. Extractor fan blockage test

For any ventilation system, the preliminary tests should be running on the system. These tests will help to inspect and examine the performance and efficiency of the system.

One of the important tests is the effect of the blockage on the system performance from the point of view of electric power consumption and airflow rate. It (the blockage) should have a non-negative effect on the static pressure inside the poultry house. Since, the value of the static pressure (10-25 Pa) is used as a gauge for poultry house good ventilation.

In our study, the effect of the blockage on our system using different levels of the shutter blades open angles to get certain degrees of blockages were as shown in Table (1).

Table (1): Shutter blades open degrees

Shutter blades open levels	**Full open**	**0.75open**	**0.5 open**	**0.25open**	**Full closed**
Shutter blades open angle	90^o	67.5^o	45^o	22.5	0^o
Blockage percent	0	25	50	75	100

Note, that the shutter blade's open angles are chosen as a blockage to the extractor fan, because it could happen in real life when there is any trouble with these blades.

It makes no sense to choose any other type of blockage, as in real life the shutter could blockage due to the tiny dirt of the poultry house (feathers, poultry manure, and feeding materials).

2. Extractor fan performance evaluation

The bare extractor fan (ventilation fan) performance is evaluated by the rate of airflow and the power consumption by the fan motor.

The airflow rate is obtained from the multiplication of average air velocity and the area of the fan- swept frontal area. The average fan air velocity is calculated by dividing the fan frontal area into several concentric circles of equal area (four circles) and averaging the measured air velocities at these circles, using the most reliable method proposed and designed by the American Association (Air Movement and control Association, AMCA.2007).

Fig. 1. shows the grid for placing the air velocity measuring points. The grid is made as a mesh 10 x 10 cm of iron wire. This pattern will not cause any obstacles to the airflow. The grid is divided into 4 circles of equal area, in each circle the measuring points are placed precisely.

Fig. 1: Measuring grid

In this method, the outlet duct area is divided by three diameters (Fig. 2) at equal intervals of 60 degrees. On these diameters, accurately locate the air velocity measuring points (traverse points). It is recommended that the number of traverse points increase with increasing duct size. The distributions of travers points for circular ducts are indicated by Table (2).

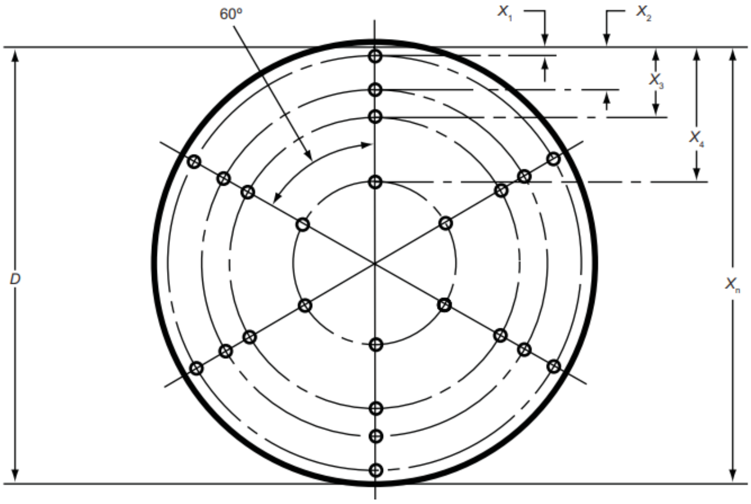

Fig. 2: Distributions of traverse points

The value X is calculated as following equation:

$$X_a = D \times K_a \quad (1)$$

Where:

D is the inside diameter of the duct

K_a is the factor corresponding to the duct size and the traverse point location as indicated in the Table 2.

Table 2: Distribution of traverse points for circular ducts.

Insid diameter of duct	Number of traverse points in each of 3 diameters	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}	K_{12}	K_{13}	K_{14}	K_{15}	K_{16}
LESS THAN 8 ft	8	0.021	0.117	0.184	0.345	0.655	0.816	0.883	0.979	_	_	_	_	_	_	_	_
8ft THROUGH 12 ft	12	0.14	0.075	0.114	0.183	0.241	0.374	0.626	0.759	0.817	0.886	0.925	0.986	_	_	_	_
GREATR THAN 12 ft	16	0.010	0.055	0.082	0.128	0.166	0.225	0.276	0.391	0.609	0.724	0.775	0.834	0.872	0.918	0.945	0.990

3. The wind turbine position

So far, there are two main concerns about placing the wind turbine facing the extractor fan. The first one is to ensure there is no negative effect on the extractor fan's performance and the second one the wind turbine should extract as much energy as possible while keeping a safe distance from the front face of the extractor fan. Besides, if the position is optimum, the performance of the wind turbine would be maximized and it also can help the extractor fan to induce more air into the poultry house.

The optimum the optimum position it will be selected according to the extractor fan air speed profile.

Also, how lucky we are, as the extractor fan diameter is 1.38 m and the HAWT propeller diameter is 1.13 m which means there is a good matching in size between them. For the distance between the extractor fan and the wind turbine, we examined the wind turbine (HAWT) at distances 10, 20 and 30cm from the front face of the extractor fan.

A supporting carrier frame was made for placing the wind turbine in the right position concerning the extractor fan. The frame (Fig. 3) is made of L iron section 2x2 cm with a telescopic tube to adjust the height of the wind turbine.

Laboratory test

Field test

Fig. 3: Wind turbine installation

RESULTS AND DISCUSSION

1. The effect of extractor fan blockage

To evaluate the effect of blockage on the extractor fan required current (which expresses the fan electric power consumption) and the change in the static pressure inside the experimental room 3.0 m width, 10 m length and 4 m height (which represented as a laboratory poultry house), simple experiments are performed, in which the shutter blades are used as obstacles. The shutter blade's open angles were used to find different degrees of blockage as mentioned in Table (2).

1.1. The effect of blockage on the fan required current

Fig. (4) shows the required current for the fan increased as the blockage degree increased. In the case of zero blockage, the shutter blades were fully open, and the fan required a current of 6.3 A represented by the horizontal dashed line in the figure. This dashed line is used as a baseline (as a base value) to indicate the changes in the required current throughout the experiments. The required current is at 25% blockage was 6.48A. This blockage causes an increment for the required current of 0.18A, which nearly equals 3% of the base value. While at 100% blockage, with shutter blades fully closed, the fan required current was 7.02A.

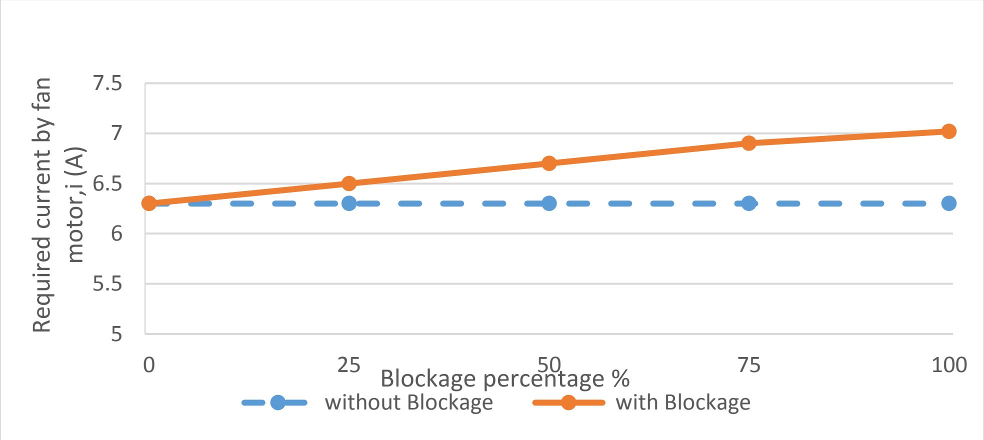

Fig. 4: The impact of blockage on the required current for the extractor fan.

The increment in the required current from zero blockage to 100% blockage (full blockage) was 0.57A. It is about 9% of the base value of the fan required current. It means the required current increased as the blockage degree increased to the complete blockage with a little increment. Since the complete blockage will not happen in our study or in real life, so, they ignore the effect of the blockage on the required current.

However, it can explain why, for the enclosed air in front of the extractor fan, a high increase in the blockage will cause a slight increase in the required current to operate the fan. Because the air had a lower mass (1.2 kg/m^3) and viscosity (18.5 10-6 Pa s), it will need a very slight of energy value to stir, and it can somehow escape from any tiny open spaces in front or even behind the fan. So, this enclosed air will not cause any additional appreciable load on the fan propeller.

1.2. The effect of blockage on the static pressure

Fig. 5. shows the effect of blockage on the static pressure inside the experimental room. The static pressure decreased sharply as the blockage increased.

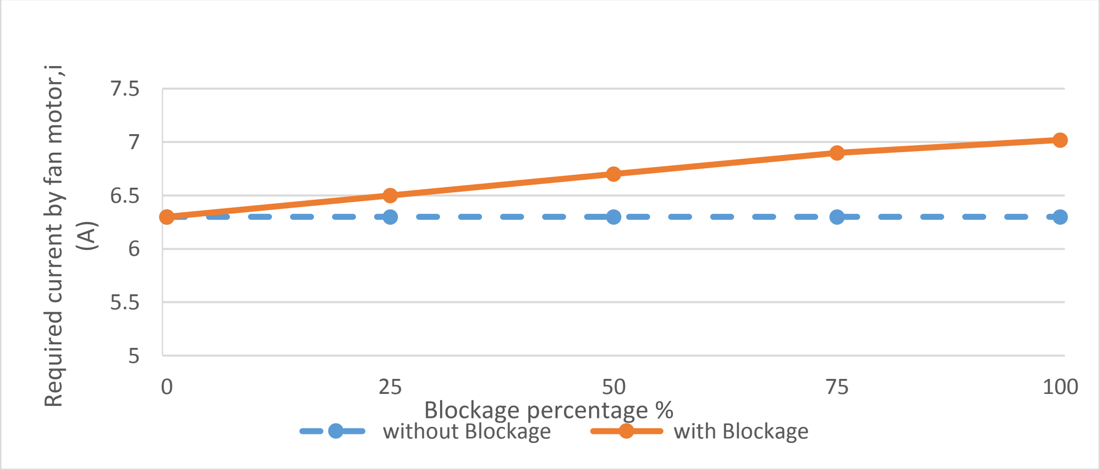

Fig. 5: Effect of blockage on the static pressure.

At zero blockage (the shutter blades fully open), the static pressure was 18 Pa dropped to 10 Pa at 25% blockage and at 100% blockage (the shutter blades fully closed) dropped to zero Pa. These results are expected because the blockage applied on the outlet area leads to blocking the flow of the air and decreases the degree of exchange of the air between the outside and inside the room.

So, from the static pressure point of view and the recommended static pressure for poultry house ventilation (10-25Pa), they that a blockage of up to 25% is acceptable for poultry house ventilation. However, to maximize harnessing the energy of the exhausted air, there should be no blockage on the ventilation system achieved using the investigated turbine.

1.3. The effect of blockage on fan rotating speed

Fig. 6. shows the effect of blockage on the extractor fan rotating speed. Without blockage (zero blockage), the extractor fan rotating speed was 430 rpm, represented in the figure by the dashed line. After applying the blockage, the fan rotating speed decreased gradually. It reached 420 rpm at a blockage of 100% with a slight reduction in the rotating speed (2%).

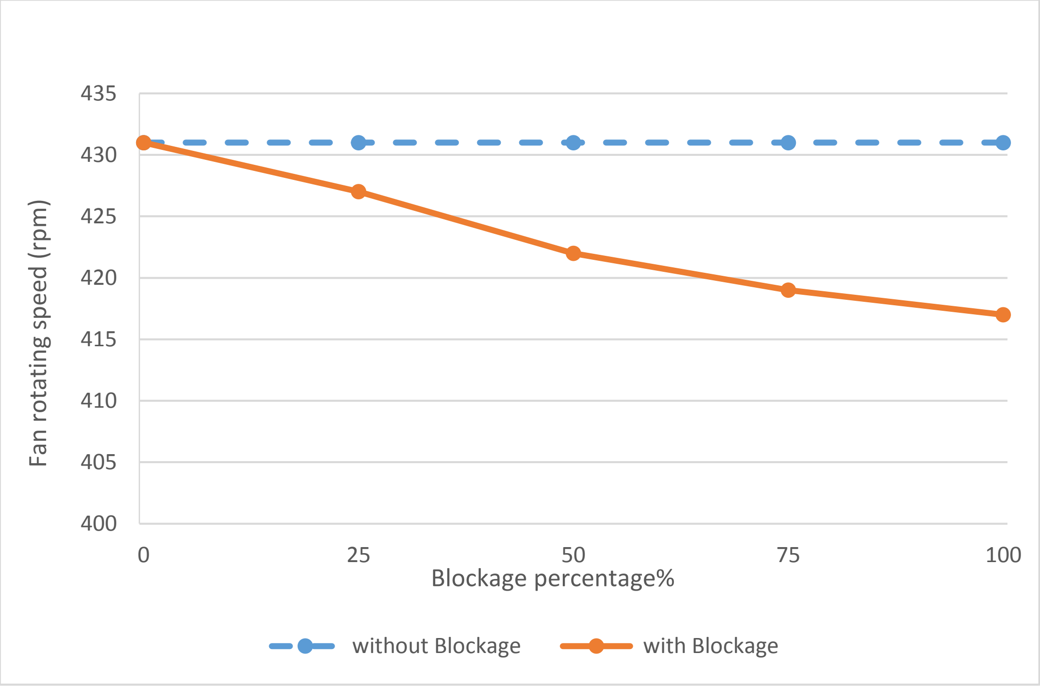

Fig. 6: Effect of blockage on the Fan Rotation

No doubt of this results, as the fan is operated and powered by its electric motor, which has a constant speed, whatever the load on the fan, as it feeds with the fixed current. Keeping in mind, the previous results about the fan required current, the blockage (even at 100% blockade) did not cause any sensible load on the fan and caused a very small increment in the feed current (9%).

2. Air velocity profile

Different configurations of exhaust air systems produce different velocity profiles of outlet air. So, the wind turbine matching has to be made according to the extractor fan air velocity profile. The mean velocity profile for our extractor fan (Fig. 7) was performed according to the method proposed by the Air Movement and Control Association (AMCA, 2007). Noting that each point on the figure is an average of three readings.

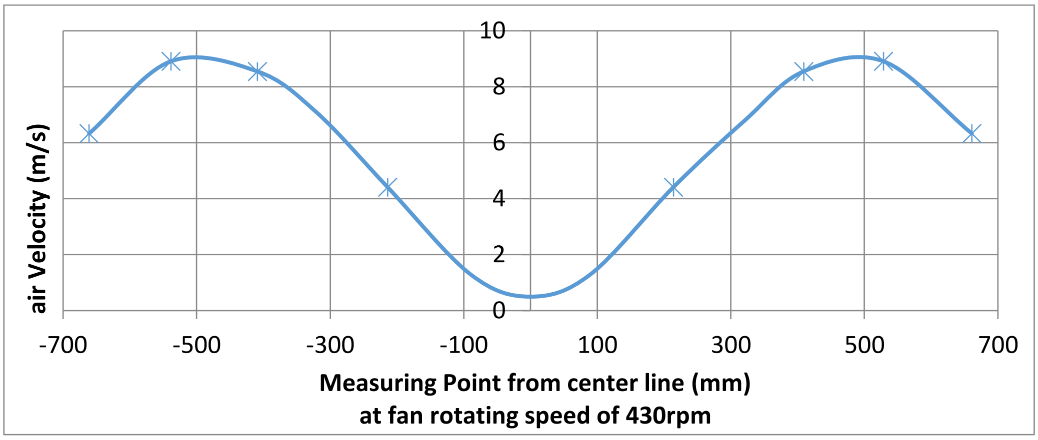

Fig 7: Mean air velocity profile at the outlet of the extractor fan.

The vertical radius of the fan duct of 690 mm is represented as the vertical dashed line. From the figure the air velocity profile was symmetrical around the center line of the fan.

The mean velocity of the exhausted air was zero at the center of the propeller of the fan and increased gradually to the maximum value (9m/s) at 500mm from the center line on both sides of the fan. The air velocity dropped gradually from the maximum value to 6.3m/s at nearly 650mm from the center line on both sides of the fan.

The air velocity recorded zero value at the center of the fan because, in this area, there is the hub (the solid central part of the fan) which acts in this area as a blockage for the flow of the air. Also due to the swirl action of the propeller of the fan which draws radially the air from the center line of the fan towards the inside wall of the duct of the fan. This swirl action of the propeller is the cause of recording maximum air velocity radially near the tips of the propeller blades. There is an empty gap (5.5 cm) between the propeller diameter (propeller blade tips) and the inside wall of the duct. In this empty gap, the air velocity dropped gradually to small values (6.3m/s) due to both the exhaust air hitting the inside wall of the duct, losing a part of its energy, and the empty gap allowing the exhausted air to extend and escape, losing another part of its energy. Depending on the air velocity profile, it could place the wind turbine in the corrected position (the area of the high air velocity) to harness most of the energy from the exhausted air.

At this moment, we can choose where to place the wind turbine. From the air velocity profile, the area of the highest air velocity ranged from 300mm up to 700 mm on both sides of the center line of the extractor fan.

Knowing that the rotor diameter for HAWT is 1130 mm and the extractor fan propeller diameter is 1270 mm, they are very close to each other. So, we can place the center line of HAWT in front of the center line of the extractor fan. Note that, the hub of each of them will be located in front of each other where the air speed at its minimum value.

3. Extractor fan with wind turbine testing

To getting the results of the performance of the ventilation system and the generated electric power when the extractor fan is loaded by the wind turbine, experiments have been done on the extractor fan before and after placing the wind turbine. The wind turbine is placed at 10, 20 and 30 cm far from the fan face, the center line of the wind turbine is located in front of the canter line of the extractor fan. The collected results were as follows, noting that each of the used values of the obtained data was an average of three readings.

3.1. Fan required current as affected by placing the wind turbine

Fig. 8. shows the effect of placing HAWT on the current required by the extractor fan. For the position of 10 cm, the decrease in the required current between the fan only and the fan with HAWT was only 1.5%. Because the placing HAWT in front of the extractor fan, the contractor to the blockage will help the extractor fan draw the air from the poultry house.

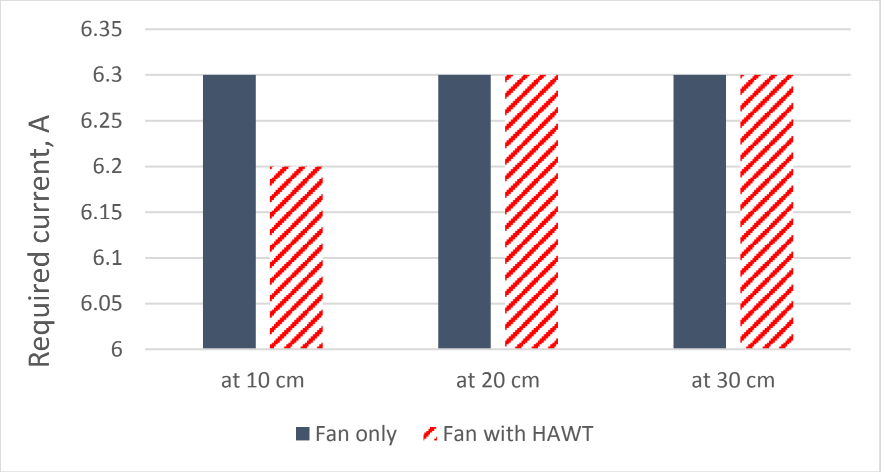

Fig. 8: Fan required current after placing HAWT

So, placing HAWT location in front of the extractor fan (for the three positions) did not have any loading effect on the fan, since the required current by the fan, and subsequently, the following power required by the fan did not change.

3.2. The effect of the wind turbine location on the static pressure

Fig. 9. shows the effect of placing HAWT on the static pressure. For the position of 10 cm the increment in the static pressure due to placing the HAWT was only 5.9%. and for the three positions, the static pressure due to placing the HAWT is, still in the recommended range for poultry house good ventilation.

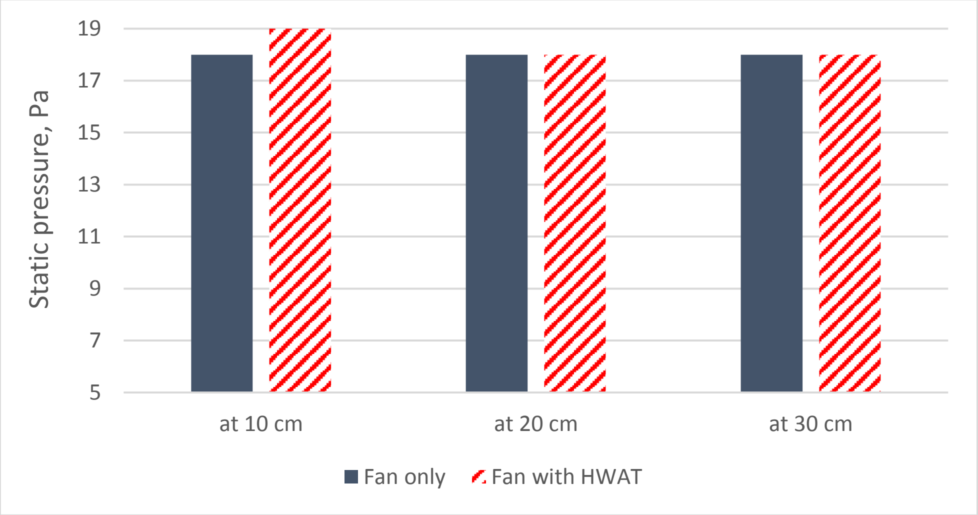

Fig. 9: Effect of the wind turbine location on the static pressure.

So, placing the HAWT in front of the extractor fan did not cause any negative effect on the static pressure.

It is because the HAWT blade number, shape and type had a slight solidity that conforms to a little obstacle to the airflow.

3.3. The effect of the wind turbine location on the fan rotational speed

It is clear from Fig. (10) that placing HAWT did not affect the extractor fan's rotational speed. This result is logical since an electrical motor operates and powers the fan.

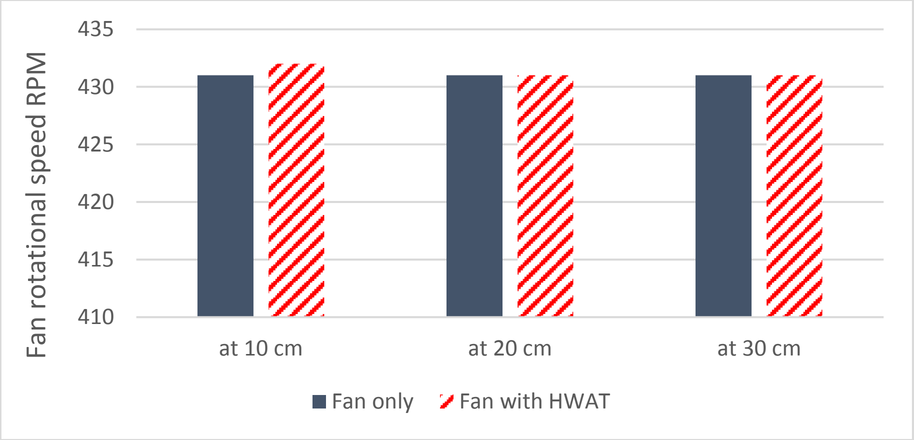

Fig. 10: Fan rotational speed as affected by location HAWT.

3.4. A case of study

If we take one poultry house of WADI Poultry Farm (Boghdady *et al.*, 2021) as a case of study for the electrical energy needed for lighting per year. In this study, for reducing the invested money, we propose to equip the poultry house with four units of the used turbine (HAWT) instead of 8 turbines (as the house is equipped with 8 ventilation fans). It can find the turbine working hours per year by inserting the number of turbines at work, with the fan yearly working hours. The turbine working hours were 30352 per year.

$$\text{HAWT} = 26.2\ (30352)\ \text{Wh/year} \approx 795.2\ \text{kWh/year}$$

In the WADI poultry farm, the lighting time was 11 hours per day. Each poultry house is provided with 130 Lamps of 0.02 kW/ lamp. So, the required electrical energy for lighting one poultry house per year will be:

$$\text{Lighting energy} = 130(0.02)\ (11)\ (365) = 10439\ \text{kWh/year}$$

So, the used HAWT, which generates 795.2 kWh/year, will provide the poultry house with a part of its needed lighting energy per year.

The generated electrical energy by the turbine covers the needed light energy for one poultry house per year by a percentage:

$$\text{HAWT} = (795.2/10439)\ {*}100 = 7.6\%. \approx 8\ \%$$

3.5 Critique of the result

The harness of the ventilation fan airflow (artificial wind) by the turbine was very low. This can be referred to two subjects, with the first one being the greatest:

1- The used turbine, its design and features:

The used turbine has been designed to suit the natural wind, which is different than the artificial wind. The artificial wind speed differs widely in the radial direction, and it has vortex.

2- The facilities to enhance the hardness of artificial wind:

To enhance the harness of artificial wind energy, we need configurations such as wind tunnel or diffuser to prevent the spread of the artificial wind and change the airflow from nonconfined flow to confined flow.

CONCLUSIONS

The turbine generated a power of 26.2 W. In a case study for a WADI company poultry farm, using 4 turbines of the used one, per house, will produce about 8% of the needed light energy per house per year. Also, the laboratory experiments show that this energy recovery system did not cause any undesirable effect on the poultry house ventilation system (the static pressure) or the ventilation fan rotation speed and its power consumption.

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استرجاع بعض الطاقة الكهربية المستهلكة في ادارة مراوح تهوية عنابر الدواجن واستخدامها في الاضاءة

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الملخص العربى

يتم تطبيق الطاقات الجديدة والمتجددة في مجال تربية الدواجن، من أجل تقليل الطلب المتزايد على الطاقة وإلى حد ما توفير أرباح بديلة محتملة للمنتجين . ولقد تم تقديم نظام مبتكر لاستعادة جزء من الطاقة من مصادر الرياح الاصطناعية (أنظمة هواء التهوية). في هذه الدراسة، تم دراسة نظام أولي لاستعادة الطاقة للتهوية في بيوت الدواجن. وكذلك تم استخدام توربينات الرياح ذات المحور الأفقي (HAWT) الموجودة عند مخرج مروحة التهوية لاستعادة الطاقة إلى جانب المكونات الإلكترونية الأخرى . وهدفت الدراسة الأولية إلى جمع بيانات عن أداء مروحة الشفط وتوربينه الرياح في سيناريوهات مختلفة وتقييم أي تأثير سلبي على نظام التهوية . وأظهرت التجربة أن أفضل وضع رأسي لمحركHWAT بقطر ١١٣٠ مم في منفذ مروحة التهوية بقطر خرج ١٣٨٠ مم، عندما يكون مركز التوربينة في مركز المروحة وعلى مسافة ١٠ سم في هذا التكوين، وتم تحسين معدل تدفق مروحة التهوية بنسبة ٠,٢٣%، وتقليل استهلاك طاقة ماتور المروحة بنسبة ١,٥٨% بينما تولد التوربينة 26.2 واط. في هذا التكوين، ويتأثر معدل تدفق مروحة التهوية بنسبة ٠,٢ % ولم يلاحظ أي استهلاك للطاقة على ماتور المروحة.